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CRITERIA FOR MUNICIPAL SOLID WASTE LANDFILLS OPERATING CRITERIA (SUBPART C)

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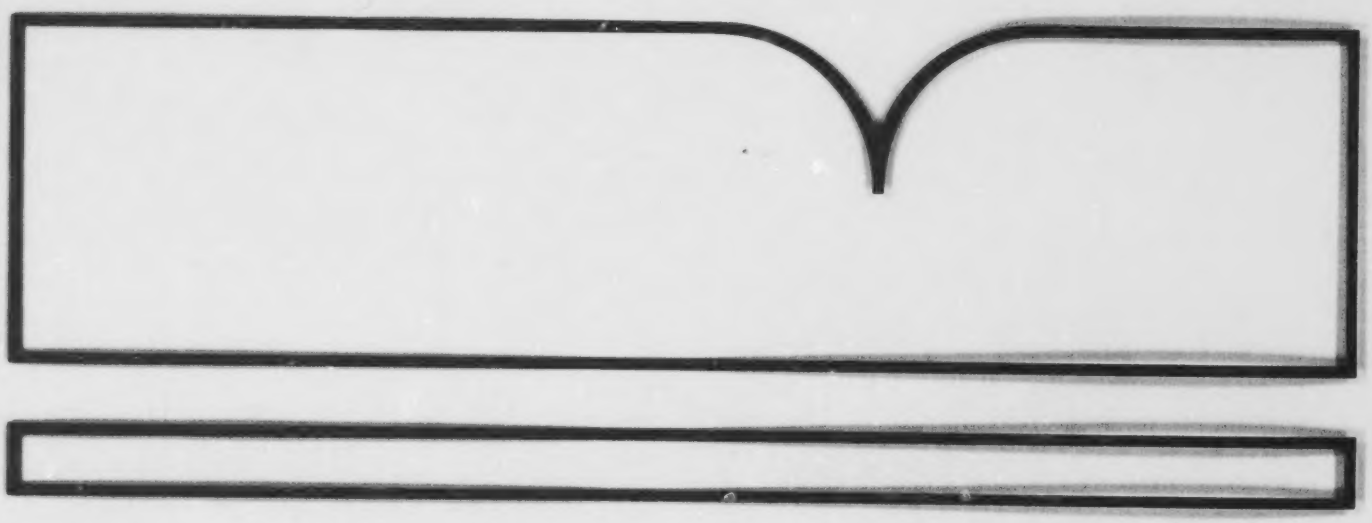

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DRAFT
BACKGROUND DOCUMENT

OPERATING CRITERIA
(SUBPART C)

"CRITERIA FOR MUNICIPAL SOLID WASTE LANDFILLS"
(40 CFR PART 258)

SUBTITLE D OF RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF SOLID WASTE

JULY 1988

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In August 1988, the U.S. Environmental Protection Agency proposed Solid Waste Disposal Facilities Criteria (40 CFR Part 258) for municipal solid waste landfills. This background document provides the technical support for Subpart "C" - Operating Criteria of Part 258.

This document contains a discussion of background information and provides detailed information on the revised operating criteria. The revised operating criteria include procedures for 1) excluding the receipt of hazardous waste, 2) cover material requirements, 3) controlling disease vectors, 4) monitoring for explosive gas, 5) complying with air criteria, 6) limiting access, 7) controlling run-on and run-off, 8) protecting surface waters, 9) restricting liquid wastes, and 10) recordkeeping

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I. INTRODUCTION

The 1984 Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) directed EPA to revise the "Criteria for Classification of Solid Waste Disposal Facilities and Practices" (40 CFR Part 257) for facilities that may receive household hazardous waste (HHW) or hazardous waste from small quantity generators (SQGs). Such revisions shall be those necessary to protect human health and the environment and may take into account the "practicable capability" of facilities to implement the Criteria. At a minimum, the revisions should require ground-water monitoring, as necessary, to detect contamination, establish location standards for new or existing facilities, and provide for corrective action as appropriate.

In carrying out this mandate, EPA has undertaken efforts to revise the current Criteria. EPA is initially limiting the Criteria revisions to municipal solid waste landfills (MSWLFs) because these are the only facilities for which the Agency has complete and reliable data, as discussed in the Revised Final Draft Report to Congress: Solid Waste Disposal in the United States, Volume I and II [EPA, April 1988]. The rationale for this choice is further discussed in the Background Document for Options Selection [EPA, Sept. 1986].

Section II of this document provides a discussion on the background information that supports the Criteria revisions and Section III provides detailed information on the development and evaluation of the general operating criteria of the revised Criteria. Additional background documents have been developed to support other aspects of the revised Criteria.

II. BACKGROUND

This section provides the legislative and regulatory background for understanding the current status of the Subtitle D program. Beginning with the legislation establishing Subtitle D of the Resource Conservation and Recovery Act of 1976, the section briefly reviews Federal and State implementation efforts from 1978 up to 1981 when Federal attention turned to the hazardous waste program and Federal funding to State Subtitle D programs ended. The section then outlines the new Subtitle D provisions contained in the Hazardous and Solid Waste Amendments of 1984 and describes EPA's major activities implementing these provisions.

A. SUBTITLE D OF THE RESOURCE CONSERVATION AND RECOVERY ACT

With the passage of the Resource Conservation and Recovery Act (RCRA) of 1976, Congress significantly expanded the Federal role in controlling the management of waste materials in the United States. Subtitle C of RCRA required EPA to establish a comprehensive regulatory program to ensure proper management of hazardous waste. Subtitle D required EPA to provide technical assistance to the States and to develop Federal criteria for controlling solid waste management practices, and authorized Federal financial assistance to help the States accomplish this effort.

Subtitle D of RCRA established a cooperative framework for involving Federal, State and local governments in dealing with solid waste problems. The Federal role in this arrangement is to provide technical assistance to States and regions for planning and developing environmentally sound waste management practices and to furnish financial assistance to enable States to implement these measures. The actual planning and implementation of solid waste programs under Subtitle D, however, remain State and local functions. The primary provisions of Subtitle D, that are discussed later in this section, include:

- Section 4002 -- Federal Guidelines for State Plans.
- Section 4004 -- Criteria for Solid Waste Disposal Facilities.
- Section 4005 -- Prohibition of Open Dumps.

In addition to these technical provisions, Section 4008 of Subtitle D authorizes EPA to provide grants to States for development and implementation of solid waste management plans, resource recovery programs, and resource conservation programs.

B. IMPLEMENTATION OF SUBTITLE D

In a series of rulemaking beginning in 1978, EPA began the process of implementing the provisions of Subtitle D. The Section 4002 guidelines for State plans were completed in 1979, and EPA began reviewing plans submitted by States and providing grants to States for program planning and implementation. The Criteria for classifying solid waste disposal facilities also were finalized in 1979. These Criteria were used by the States to classify facilities as either "sanitary landfills" or "open dumps". EPA published the first inventory of open dumps in 1981. In that year, however, Federal funding for State nonhazardous waste programs that implemented and enforced the Criteria was terminated.

Guidelines for State Solid Waste Management Plans

Pursuant to RCRA Section 4002(b), EPA promulgated guidelines for the development and implementation of solid waste management plans on July 31, 1979 (44 FR 45066). These guidelines identify the minimum statutory requirements that State plans must address and also deal with a full range of solid waste management, materials conservation, and resource recovery issues.

As the centerpiece of the Subtitle D program, the State solid waste management plan serves a critical function. It is through this plan that each State identifies a general strategy for protecting public health and the environment from adverse effects associated with solid waste disposal, specifies efforts for encouraging resource recovery and resource conservation, and formulates plans for providing adequate disposal capacity within the State. The plan also describes the institutional arrangements that the State will use to implement its solid waste management program.

Under Subtitle D, EPA reviews and approves State plans that meet the Agency guidelines. As of June 1988, EPA has fully approved 25 States' solid waste management plans and partially approved another six. EPA also had authority to provide grants to States to assist them in development and implementation of their plans. However, EPA discontinued those solid waste grants in 1981 when the focus of the Federal program turned to hazardous waste.

Federal Criteria for Solid Waste Disposal Facilities

Pursuant to RCRA Sections 4004(a) and 1008(a)(3), EPA proposed Criteria for classifying solid waste disposal facilities on February 6, 1978 (43 FR 4942). Final Criteria were promulgated on September 13, 1979, and minor modifications were issued in September 1981. These Criteria are entitled the "Criteria for the Classification of Solid Waste Disposal Facilities and Practices", and are found at 40 CFR Part 257. They provide minimum national standards for any solid waste disposal facility or practice, including landfills, surface impoundments, land application units, and waste piles. The Criteria include general environmental performance standards that establish the level of protection necessary to ensure that "no reasonable probability of adverse effects on health or the environment" will result from operation of the facility. A facility that meets these Criteria is classified as a "sanitary landfill"; a facility in violation is classified as an "open dump" and must be upgraded or closed.

Implementation and enforcement of these Subtitle D Criteria are the responsibility of State and local governments. In addition, private citizens may use RCRA's citizen suit provisions to bring actions in Federal court to enforce the Criteria against violators.

C. SUBTITLE D PROVISIONS OF HAZARDOUS AND SOLID WASTE AMENDMENTS OF 1984

On November 8, 1984, the Hazardous and Solid Waste Amendments of 1984 (HSWA) were passed. These amendments affected virtually every part of the RCRA program, including solid waste management.

Section 302 of these Amendments directed EPA to study and revise the Criteria, as well as examine the need for additional enforcement authorities. This Section states that EPA must "conduct a study of the extent to which the (Criteria)...applicable to solid waste management and disposal facilities, including, but not limited to landfills and surface impoundments, are adequate to protect human health and the environment from ground water contamination." This study, which must be completed and delivered to Congress in report form "shall also include recommendations with respect to any additional enforcement authorities which the administrator, in consultation with the attorney general, deems necessary" to protect ground water.

In addition to the study, Section 302 of HSWA requires EPA to promulgate revised Subtitle D Criteria for facilities that receive hazardous household waste or hazardous waste from small quantity generators. HSWA states that such revisions "shall be those necessary to protect human health and the environment and may take into account the practicable capability of...facilities [to implement the Criteria]. At a minimum, [the] revisions...should require ground- water monitoring as necessary to detect contamination, establish criteria for the acceptable location of new or existing facilities, and provide for corrective action as appropriate."

HSWA also requires each State to establish by November 8, 1987, a permit program or other system of prior approval for facilities receiving small amounts of hazardous waste. This permit program is meant to ensure that such facilities are in compliance with the Criteria. Within 18 months of EPA's promulgation of the revised Criteria, each State must modify its permit program or alternate system accordingly. If a State fails to develop and implement an appropriate permit program, or other system of prior approval, EPA is given the authority to enforce the Criteria at facilities accepting household hazardous waste or small quantity generator waste.

D. SUBTITLE D STUDY AND CRITERIA REVISIONS

EPA is currently proceeding with implementation of HSWA's Subtitle D requirements, including the completion of the Subtitle D study and the development of the Criteria revisions. The major objectives of the Subtitle D study are to identify, characterize, and evaluate the environmental and human health

impact of all solid waste disposal facilities and to determine the adequacy of the current regulatory program and Subtitle D enforcement authorities. The Subtitle D study was conducted in two phases. During Phase I of the study that was completed in October 1986, EPA used existing information gathered from the literature, States, EPA files, voluntary submissions from facility owners or operators, and any other available sources to address the objectives of the study.

In Phase II, which is still proceeding, EPA will concentrate on filling the information gaps identified during Phase I through collection of additional existing data and original data collection efforts. Phase II will result in the completion of the Subtitle D study report and its submission to Congress.

At the same time, EPA is developing changes to the Subtitle D Criteria for facilities that receive household hazardous waste and small quantity generator hazardous waste. This document provides detailed background data and information that was used to develop and evaluate the general facility operating criteria for new and existing municipal solid waste landfills.

III. DEVELOPMENT OF OPERATING CRITERIA

A. OBJECTIVE

This Section provides the background information and discussion of the alternatives considered for general facility operating criteria for all municipal solid waste landfills (MSWLFs) regardless of location. The general facility criteria addressed in this chapter include: procedures for excluding the receipt of hazardous waste; application of daily cover; control of disease vectors; explosive gas control and monitoring; open burning; compliance with State Implementation Plans; access controls; run-on/run-off controls; surface water protection; liquids restriction; and recordkeeping requirements. In general, these requirements are location-independent and should be implemented based on site specific conditions. Closure, post-closure care, and financial responsibility criteria are addressed in separate background documents specific to these topics.

B. PROCEDURES FOR EXCLUDING THE RECEIPT OF HAZARDOUS WASTE

Because the requirements for siting, monitoring, designing and operating MSWLFs are less comprehensive and less stringent than the corresponding requirements for hazardous waste landfills, MSWLFs are not suitable for the receipt of regulated quantities of hazardous waste. For this reason, procedures to deter the illegal dumping of hazardous wastes at MSWLFs are needed in order to adequately protect human health and the environment. The purpose of the procedures for excluding the receipt of hazardous waste is to identify and prevent, to the extent possible, the disposal of regulated hazardous waste in MSWLFs. Owners and operators of MSWLFs will be required to institute a hazardous waste screening program that incorporates 5 elements: random inspections of incoming loads, inspection of all suspicious incoming loads, recordkeeping of inspection results, training of facility personnel to recognize hazardous waste, and procedures for notifying the proper State authorities if a regulated hazardous waste is found at the facility.

The random inspection requirement is intended to discourage the illegal dumping of regulated hazardous wastes at MSWLFs. While a random inspection will not stop every regulated hazardous waste entering a MSWLF, awareness that such a

program is in place will provide substantial deterrence to the practice of illegal dumping without serious disruption of facility operations. EPA is further requiring that all suspicious incoming loads be inspected. Training of all MSWLF personnel to recognize containers and markings typically used for hazardous waste disposal, and gain the skills necessary to identify "suspicious" loads is also required. Records of all inspections must also be maintained in order to provide a list of sources that have previously attempted to deliver regulated hazardous wastes to MSWLFs, so that special precautions can be taken when accepting wastes from these sources in the future.

Finally, the rule requires that every facility's waste screening program contain provisions for notification of the proper State authorities upon receipt of regulated hazardous waste. This requirement assures that proper cleanup, transport, and disposal of the regulated hazardous waste at a permitted facility will ensue if it is presented for improper disposal.

EPA considered detailed requirements for waste screening which would clearly specify all waste screening activities that MSWLF owners and operators must employ. However, the Agency believes that the current plan provides the States and the MSWLF owners and operators with more flexibility than such a detailed set of requirements, while at the same time acting to prevent the disposal of regulated hazardous waste at MSWLFs.

C. COVER MATERIAL

The preamble to the current Subtitle D Criteria [44 FR 53456, September 13, 1979] states that the daily application of soils or other suitable cover materials at MSWLFs serves the following functions :

- It controls the escape of odors, litter, and air emissions,
- It reduces the potential for fires,
- It reduces rain water infiltration, thereby decreasing leachate generation and surface and ground-water contamination,

- It improves the facility's appearance and enhances utilization after completion,

- It controls onsite populations of disease vectors, and

- It discourages scavenging.

The performance standard in the current Criteria (40 CFR, 257.3-6(a) Disease and 40 CFR 257.3-8(b) Safety) requires that cover be applied periodically to control the on-site population of disease vectors and to control fires. The other problems that the application of cover material help control are either addressed in other parts of the criteria (e.g., 40 CFR 257.3-7 Air for air emissions) or are considered best addressed at the State or local level (e.g., litter). Because the current Criteria address many types of Subtitle D facilities, such as surface impoundments and land application units, the application of cover is optional and other methods to meet the performance standard may be implemented if appropriate.

In revising the Criteria the Agency considered two options: (1) retain the standard currently found in 40 CFR 257.3-6 and 257.3-8 of requiring the periodic application of cover as necessary, or (2) require the application of cover at the end of each operating day with variances from this requirement allowed on a case-by-case basis.

The preamble to the Part 257 criteria [44 FR 53456, September 13, 1979] indicates that alternative methods to the periodic application of cover material were allowed in the existing regulations because "It is impractical...to cover some wastes. Moreover, cover material is not generally necessary for wastes which are non-putrescible, relatively stable, or inert. The criteria allow for other techniques to be employed in these situations."

These other techniques include the use of repellants, insecticides or rodenticides, waste composting or processing, and predatory or reproductive control [EPA, SW-828, 1980].

MSWLFs, however, accept wastes that consist of a wide variety of materials. In particular, such facilities receive wastes that contain putrescible materials (residential wastes contain approximately 8% food wastes and 37% paper products [EPA, 530-SW-86-054, October, 1986]). The disposal of such materials in MSWLFs results in conditions conducive to the harborage of rodents and other disease vectors. The application of cover at the end of each operating day is an accepted method for reducing such conditions [Noble, 1976; Brunner et al, 1972].

Although the alternate methods discussed may be effective under certain circumstances, they may also result in other environmental or public health problems (particularly the use of chemical controls) which the Agency wishes to avoid. In addition, such alternative methods, by themselves, may not always be appropriate in controlling other problems such as blowing litter or fires, that may occur at MSWLFs.

For these reasons, EPA believes it necessary to make the use of daily cover mandatory at MSWLFs (with opportunity for very limited exemptions on the basis of extreme climatic conditions).

The requirement to apply daily cover specifies the application of "suitable materials at the end of each operating day, or at more frequent intervals if necessary, to control disease vectors, fires, odors, blowing litter and scavenging." In choosing this particular requirement, EPA examined the components of State and territorial requirements for application of cover materials [PEI, 1986]. (See Attachment 1 and 2, Appendix A). Forty-five (45) States and territories require the daily application of cover material. Most States and territories require daily application of six inches of cover at MSWLFs. Some States grant exemptions to this requirement, while others specify more stringent procedures. The requirements of the different States are discussed below.

Frequency of Applicaton

Although 45 States and Territories require the application of daily cover at MSWLFs, several States have exemptions to daily cover requirements. Exemptions are generally granted on the basis of one of the following criteria [PEI, 1986]:

- Size of the population served by the landfill (4 states),
- Distance to the nearest residence or place of public gathering (1 state), or
- Amount of waste received at the landfill (5 states).

The Agency does not have information that supports the use of the above criteria for allowing exemptions from the daily cover requirement at MSWLFs that accept putrescible wastes. It is recognized, however, that there may be situations where daily application of cover may be difficult or impossible; for example, when cover stockpiles are frozen or when heavy snowfall make it impossible to spread the cover. Therefore, EPA has chosen to allow limited exemptions to the daily cover requirement, in cases of such extreme climatic conditions.

Depth of Cover

The Criteria do not specify a required cover depth. It is recommended, however, that a 6-inch depth of compacted earthen material be applied at the end of each operating day. The use of earthen material is a standard practice at most MSWLFs, and it is widely accepted that a minimum compacted thickness of 6-inches of soil will control vectors, litter, fires, and moisture infiltration [Brunner and Keller, 1972; Weiss, 1974]. Non-earthen materials, however, may also meet the performance standard and provide the same protection as earthen material.

Characteristics of Cover Material

Many States require that cover material have particular characteristics such as good compactability, ability to provide an adequate seal, and ability to prevent excess infiltration of water [PEI, 1986]. Some States go further and designate a range of suitable soil classifications, or specify the fraction of the cover soil that must pass through a sieve of a particular size. One State specifies the maximum coal and/or combustible content of the soil.

Peat and highly organic soils are not recommended to be used as cover material because they are difficult to compact [Weiss, 1974]. Table 1, reprinted from Weiss [1974], describes the suitability of general soil types to serve the different functions of cover material.

EPA has chosen to make its requirements for daily cover broad, allowing the States the flexibility to require more specific practices. Aspects of daily cover application that EPA does not address in the rule include requirements for grading daily cover to control erosion and ponding, and requirements for maintaining a stockpile of fill at the landfill site sufficient to last for a certain period of operation. EPA has left it to the States to specify these requirements if they so choose.

D. DISEASE VECTORS

MSWLFs can provide food, shelter, and breeding areas for disease vectors. Disease vectors are animals or insects such as rats, flies, and mosquitoes, that can transmit disease to humans. Some diseases associated with these vectors are rat bite fever, leptospirosis, plague, salmonellosis, trichinosis, murine/typhus fever, encephalitis, malaria, and yellow fever [Noble, 1976; EPA Background Document: Disease. 1979]. Landfills, especially those which accept putrescible waste, can provide an ideal environment for a high concentration of disease vectors. Thus, EPA requires that MSWLFs concientiously monitor the disease vector population and follow practices that keep the vector population to a minimum. Since measuring specific population levels would be difficult or impossible, EPA has chosen to require MSWLF operators to minimize the vector population through prevention and control techniques.

The 1979 Criteria require the application of daily cover material, or other "...techniques appropriate for the protection of human health and the environment." Such techniques include, but are not limited to, stabilization of the waste and using repellants, poisons, or reproductive or predatory controls.

Periodic application of cover material (usually soil) is the most widely-used form of disease vector minimization. However, because periodic application of cover material is essentially a standard landfilling practice that serves many uses in addition to disease vector control, EPA is treating Cover Material and Techniques

Table 1

Suitability of General Soil Types as Cover Material

Function	Clean gravel	Clayey-silty gravel	Clean sand	Clayey-silty sand	Silt	Clay
Prevent rodents from burrowing or tunneling	G	F-G	G	P	P	P
Keep flies from emerging	P	F	P	G	G	E†
Minimize moisture entering fill	P	F-G	P	G-E	G-E	E†
Minimize landfill gas venting through cover	P	F-G	P	G-E	G-E	E†
Provide pleasing appearance and control blowing paper	E	E	E	E	E	E
Grow vegetation	P	G	P-F	E	G-E	F-G
Be permeable for venting decomposing gasψ	E	P	G	P	P	P

* E, excellent; G, good; F, fair; P, poor.

† Except when cracks extend through the entire cover.

ψ Only if well drained.

Source: Weiss, 1974.

for Disease Vector Control as separate topics (see Section III. C of this document for discussion on cover material) in the revisions to the Criteria.

Other techniques that may be used to control disease vectors, besides daily cover, include various waste stabilization methods that prevent the establishment of disease vector populations. Shredding wastes that provide potential harborage for rodents or insect larvae (e.g., automobile tires, where rats may hide and where disease-carrying mosquitoes multiply roughly 4,000 times faster than in forests [Grady, 1987]) is one method that helps prevent a large vector population from developing. Incorporating putrescible waste material into the soil also is an effective prevention technique. Treating the waste with a process, such as biological degradation or composting, may also be necessary, or sometimes even acceptable in lieu of incorporating the waste into the soil [EPA, SW-828, 1980].

When it is impractical to apply cover material, or when the application of cover material is insufficient to control disease vectors, the judicious use of poisons (insecticides and rodenticides) is an effective control measure. Flies generally have the highest population during summer months, and are controlled effectively by daily application of an insecticide such as malathion, naled, or Diazinon [Brunner and Keller, 1972]. Insecticide sprays also can be used to control mosquito populations. Rodenticides can be used to reduce the rat population, but serve strictly as a short-term solution when daily cover is insufficient to prevent rats from flourishing at the MSWLF. It should be noted that any and all uses of insecticides or rodenticides should be in accordance with the manufacturers specifications to avoid any adverse impacts to the environment.

Predatory or reproductive controls can help minimize the vector population. For example, organisms that feed on mosquito larvae could be introduced to the facility. Another method which aids in preventing large mosquito populations from forming is agitating and/or varying the level of standing water (e.g., leachate collection ditches) [EPA, SW-828, 1980].

The rule is a performance-oriented standard that allows the MSWLF operator to select the technique or techniques that will, in combination with daily cover, most effectively minimize the MSWLFs disease vector population.

E. EXPLOSIVE GASES

The anaerobic bacterial decomposition of organic matter in MSWLFs (in particular, household refuse) produces explosive gases, predominantly methane. MSWLF gas usually consists of 50 percent methane and 40 to 50 percent carbon dioxide, plus 0.5 to 1 percent of hydrogen, oxygen, nitrogen, and other trace gases. Attachment 3 in Appendix A presents data on the composition of typical gases from MSWLFs.

Within a MSWLF, methane is produced after the conditions in the voids within the waste change from aerobic to anaerobic and the chemically available oxygen in the refuse is consumed. The process of gas production is controlled by local site conditions that affect the bacterial population, such as pH, temperature, moisture and oxygen content (both gaseous and chemically available).

Generation of landfill gas creates a pressure build-up that forces the gas to migrate laterally and/or vent to the atmosphere. The two basic mechanisms by which gases migrate are molecular diffusion and convective mass transfer. Generally, convective or pressure-induced flow is the predominant mechanism of subsurface gas flow compared to molecular diffusion which is slow. The "Technical Issues Paper on Subsurface Gas Migration" [GCA, 1986] provides more detail on these two gas migration mechanisms.

The methane component of MSWLF gas can create an explosive hazard. Migrating methane has forced the evacuation of nearby residences and businesses. It has been responsible for on-site and off-site fires, explosions, property damage, human injury, and in some cases, death. [GCA, 1986]. Attachment 4 in Appendix A presents data on Subtitle D and hazardous waste co-disposal sites where subsurface gas migration has caused damages. In addition to property damage, ground-water contamination and vegetative destruction on site and on adjacent lands have resulted from landfill gas migration [EPA, Letter Report, March 1, 1977].

Standard

For the reasons discussed above, EPA established an explosive gas criterion in the original Subtlitle D Criteria under 40 CFR 257.3-8(a) that set concentration limits for explosive gases (methane) in facility structures and at the property boundary. This standard states that concentration levels for methane are not to exceed the lower explosive level (LEL) in soil at the property boundary (5 percent methane); and 25 percent of the LEL in on-site structures (1.25 percent methane). The human health standard for methane is greater than the LEL, therefore, EPA believes the current limits provide adequate protection to human health and the environment at the property boundary and the 25 percent of the LEL for on-site structures allows for a margin of safety. In selecting the 25 percent figure, EPA is using a safety factor recognized by other Federal agencies as being appropriate for similar structures including regulations established by the Occupational, Safety and Health Administration and National Fire Protection Codes.

Preventive Measures

There are numerous measures available to prevent or control the formation and migration of landfill gases. The final method selected will depend upon site-specific conditions (e.g., soil type, geology, hydrology, climatic conditions). Methods that have been used to control gas migration include one of the following [EPA, 1977; Raymond Vail and Associates, 1979]:

- Permeable trench (gravel trench),
- Semi-permeable barrier (synthetic liner or clay liner) in conjunction with a gravel trench (trench barrier system),
- Venting system with gravel trench or gravel layers (passive landfill vent control systems), or
- Venting with a gas pumping system (active landfill vent control systems).

The permeable trench, that collects and vents the gas, is usually placed at the perimeter of the site where gas migration is of most concern. The trench is generally installed to a depth equal to the depth of the site. This is not always the best approach, however, because gas may migrate under the trench. Ideally the trench should be installed to ground water or to an impermeable geological barrier. This passive method of venting, however, has been shown to have a low percentage of success for controlling gas migration [EPA, Letter Report, March 1, 1977; Raymond Vail and Associates, 1979].

A gravel trench in conjunction with a semi-permeable liner (trench barrier system) provides a more effective barrier. This system should be installed to the water table and care must be used during the installation of the liner material to avoid tears [EPA, Letter Report, March 1, 1977; Raymond Vail and Associates, 1979]. Attachment 5 (Appendix A) is a diagram of a trench barrier system.

A pipe venting system in conjunction with a gravel trench (passive landfill vent control system) is about as effective for controlling gas migration as the gravel trenches used alone. This system, however, is more costly than the above two methods and may be subjected to vandalism [EPA, Letter Report, March 1, 1977].

The pumping system or active landfill vent control system provides the greatest effectiveness of gas migration control but is more costly to install and maintain. This system incorporates a series of wells (that do not have to be installed to the water table) that withdraw the gas from the landfill or from the area surrounding the landfill. Generally if the gas is to be recovered and used as an energy source, it is recovered from the landfill using an active vent system. Thus recovery and migration control are accomplished in a single process. When gas migration is to be controlled, pumping wells are installed between the source of the gas and the threatened building, home, etc. Systems may be designed to operate only when a certain concentration of methane is detected; this prevents continuous operation [EPA, Letter Report, March 1, 1977]. Attachment 6 (Appendix A) is a diagram of an active and a passive landfill vent control systems.

The Raymond Vail and Associates', Investigation of Methane Gas Problems at High Priority Waste Disposal Sites [1979] provides more detail on the gas migration control systems discussed above.

Gas Monitoring

EPA believes that gas monitoring is necessary to determine if compliance with the standard is being achieved and to protect human health and the environment. The table of damage cases resulting from methane gas migration from MSWLFs in Attachment 4 (Appendix A), lists twenty-three (23) incidents that have occurred since the promulgation of the 1979 Criteria (which did not require gas monitoring). These case studies describe incidences of fires or explosions (14), evacuation of off-site structures (9), injuries (7), and death (3). EPA believes that many of these incidences may have been prevented if routine gas monitoring had been conducted to detect dangerous gas levels. Early warning may have allowed the owner or operator to implement corrective action. Therefore, EPA has included a standard in the criteria that requires monitoring for methane gas at on-site facility structures and at the property boundaries.

Methane is the constituent of concern because MSWLFs receive organic putrescible wastes that promote the generation of methane gas and it is the principal source of explosions associated with solid waste disposal. Attachment 7 in Appendix A is an issues and options paper presented by SCS Engineers to EPA on "Landfill Gas Issues and Options." This paper contains discussions on gas constituents of concern and their standards, gas monitoring needs, types of monitoring, and summaries on the options that were evaluated.

The gas monitoring frequency should be conducted at least quarterly. Quarterly monitoring accounts for the seasonal variations in subsurface gas migration patterns. However, because the rate and extent of methane migration is influenced by a number of site-specific factors, including the soil conditions, hydrogeologic and hydraulic conditions surrounding the disposal area, and location of facility structures and property boundaries, more frequent methane sampling (or monitoring) should be determined by the State on a case-by-case basis. These site specific factors should also be used in determining the location of the sampling

points. EPA's guidance manual on Classifying Solid Waste Disposal Facilities [EPA, SW-828, 1980] provides information on determining the migration distances for methane that can be used in order to determine monitoring locations and frequency.

MONITORING IN FACILITY STRUCTURES

Monitoring in a facility structure normally should be done after the building has been closed overnight or for a weekend. Because landfill gases are generally heavier than air, sampling should be done in confined areas where gas may accumulate, such as, basements, crawl spaces, near floor cracks, attics, and around subsurface utility connections. If all the readings are less than 25 percent of the LEL, the MSWLF will be in compliance but the presence of any amount of methane in a structure should be considered a dangerous situation. The methane could reach explosive levels between monitoring times or at locations not a part of the monitoring plan. EPA recommends that monitoring in facility structures be conducted on a continuous basis in order to provide maximum protection from gas buildup that can lead to explosions.

MONITORING AT THE PROPERTY BOUNDARY

For monitoring along property boundaries, monitoring points should be located along the property boundaries closest to residences or other potentially affected structures. The exact location and number of these points should take into account any gas permeable seams. These might include dry sand or gravel beds, alignment with an off-site point of concern, proximity of the waste deposit, areas where there is dead or unhealthy vegetation that might be due to gas migration, and areas where underground construction may have created a natural path for gas flow (e.g., utility lines) [EPA, SW-828, 1980].

Ideally monitoring should be conducted at the property boundaries when the soil surface has been wet or frozen for several days. The results, location, date, and time should be recorded. If any of the readings are equal to or greater than the LEL, then the facility will not be in compliance. It may be necessary to repeat the tests at a later date or under different climatic conditions to verify the readings. Where

active control systems are being used, samples should be taken when all pumps have been shut down for their maximum time during normal operation [EPA, SW-828, 1980].

Monitoring at the property boundary could be accomplished by using a permanent well or a portable monitoring device. Meters normally used measure methane concentration as a percentage of the LEL rather than percent methane. Some models are equipped to measure both. High concentrations of methane (75 percent) sometimes cause erratic performance with the percent LEL meter. Therefore, meters which are capable of reading methane concentrations directly are recommended as a check in the event of erratic percent LEL readings. Alternate instrumentation could include the collection of samples in vacuum bottles, with lab analysis using a gas partitioner or chromatograph [EPA, SW-828, 1980]. EPA's guidance manual on Classifying Solid Waste Disposal Facilities [EPA, SW-828, 1980] provides additional guidance on types of monitoring devices that can be used.

Summaries of technical reports on landfill gas that were compiled by SCS Engineers has been included in Appendix A, as Attachment 8 for further information on landfill gases and the collection of methane. These reports include discussions of leachate and gas production and recovery, volatile organic compounds found in landfill gases, impacts caused by methane recovery, and demonstration of landfill gas enhancement techniques.

F. AIR CRITERIA

Open Burning

Open burning is defined as the "combustion of solid waste without: (1) control of combustion air to maintain adequate temperature for efficient combustion, (2) containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and (3) control of the emission of the combustion products," [40 CFR 257.3-7]. Open burning has been known to be a potential health hazard, to cause property damage and to be a threat to public safety. Smoke from open burning can reduce aircraft and automobile visibility and has been linked to automobile accidents and death on

expressways. Several examples of damages that have occurred due to open burning were discussed in the background document on air for the existing "Criteria for Classification of Solid Waste Disposal Facilities," 40 CFR Part 257 [EPA, July 1979]. These examples are presented below:

- In February 1968, a seven-year old boy was burned to death at the Kenilworth dump in Washington, D.C.

- In October 1973, there were 9 separate multiple-car accidents involving 66 vehicles that resulted in 9 fatalities and 34 injuries on the New Jersey Turnpike. The cause of the accidents was reduced visibility due to smoke from nearby dump fires.

- A man died and a child was severely burned by trash fires in 1972 in St. Joseph, Missouri.

- Air traffic at airports in Maine and California has been interrupted by smoke from dump fires.

In addition to these damages, the air emissions associated with open burning are much higher than those associated with municipal incinerators with air pollution control devices, as shown in Table 2.

Because of these concerns, and in order to protect human health and the environment, a prohibition on open burning was incorporated into the existing air criteria for 40 CFR Part 257 with allowances for infrequent burning of agricultural wastes, silvicultural wastes, land clearing debris, diseased trees, debris from emergency cleanup operations, and ordnance. EPA has retained this standard in the revised criteria because of the environmental concerns and because open burning is not a recommended solid waste disposal practice and should be replaced with more advanced techniques or disposal practices. The Agency believes that the infrequent burning of the allowed waste types should be conducted in areas dedicated for that purpose and at a distance away from the landfill unit so as to preclude the accidental burning of other solid waste.

Table 2

Average Emissions of Air Pollutants[1]
[In pounds per ton]

Air Pollutants	Open Burning	Municipal Incinerator	
		Wet Scrubber	ESP[2] Unit
Particulate[3]	16	3.7	2.1
Carbon monoxide	35	35.0	35.0
Hydrocarbons[4]	30	1.5	1.5
Nitrogen Oxides	6	3.0	3.0
Sulfur oxides	1	2.5	2.5

1 Source - "Proposed Classification Criteria for Solid Waste Disposal Facilities," 40 CFR Part 257, EPA, 43 FR 4942-4955, February 6, 1978; and

Original Source - "Compilation of Air Pollutant Emission Factors," EPA, Report No. AP-42, 2d edition.

2 Electrostatis precipitator

3 The EPA new source performance standard (40 CFR Part 60) for particulate emissions from new incinerator facilities corresponds to 1.5 lbs/ton of waste.

4 Expressed as methane (CH4)

EPA is aware that several States allow the routine open burning of solid wastes besides those already allowed if the amount of wastes are small or if the burning occurs in remote areas. The major advantages claimed are that it reduces volume, thereby extending landfill life and reducing costs for small communities, and that it helps reduce disease vectors. EPA recognizes that some volume reduction is achieved, however, the Agency has no data that indicates that disease vectors are significantly reduced. For the most part, such variances appear to be based on the practicable capability of the regulated community and are different from environmental variances. The Agency, however, has no information that indicates that the threats to human health and the environment, posed by the open burning of solid waste, are any less under such circumstances or that the practicable capability of small communities will be strained by complying with the ban. The inclusion of such variances based on practicable capability in the Criteria, therefore, was also rejected.

State Implementation Plan

The current 40 CFR Part 257 Criteria requires compliance with State Implementation Plans (SIPs) under Section 110 of the Clean Air Act. EPA instituted this requirement to coordinate the Criteria with the Clean Air Act because regional health concerns addressed through the SIPs clearly are of concern under RCRA as well. The standards (discussed previously) that prohibit open burning are expected to prevent most air quality problems associated with MSWLFs. However, where air emission problems are not covered by these standards, EPA believes it is important that SIPs are complied with and the standard requiring SIP compliance be retained in the revised Criteria.

Other Air Concerns

MSWLFs also appear to be a significant source of other types of air emissions. Gases originate within the landfill and vent to the atmosphere by vertical migration and/or lateral migration. Landfill gas is generated "in-situ", within MSWLFs, by chemical reactions and by microbial degradation of refuse materials into a variety of simpler compounds. Typically, landfill gas consists of approximately 50%

methane, 50% carbon dioxide, and trace constituents (up to 2%) of VOC and toxics. Toxic constituents commonly found in MSWLF gas include vinyl chloride, benzene, trichloroethylene, and methylene chloride. Nationwide air emissions of nonmethane organics are estimated to range from 150,000 to 200,000 Mg/yr for active MSWLFs. Some of these compounds emitted from MSWLFs can also create an odor nuisance.

Air emissions from MSWLFs can be controlled by collecting and controlling (or recovering) the extracted landfill gas. At approximately 100 landfills, gas is collected and sold because of the economic recovery of methane as an alternate energy source. Control systems can be economically attractive due to energy recovery, especially at larger landfills. Sites controlling or recovering landfill gas occur in many States, including California, Maryland, New Jersey, New York, Ohio, Oregon, Texas, Wisconsion, and Washington.

EPA plans to regulate MSWLF air emissions under the Clean Air Act and to propose air emission standards for MSWLFs in the near future.

G. ACCESS

Controlled access to MSWLFs is necessary to prevent injury to the public from landfill hazards and to ensure that all wastes are properly disposed of once at the site. Nearly all States and territories (47) require some method of preventing uncontrolled access to MSWLFs [PEI, 1986]. Sources of potential injury at MSWLFs include [EPA, SW-828, 1980]:

- Operations involving heavy equipment and haul vehicles,
- Waste related hazards; such as, sharp objects, and pathogens,
- Accidental or intentional fires, and
- Excavations and other earth moving activities.

Persons have suffered injury and death as a result of uncontrolled access to MSWLFs. In 1968 a seven year-old boy was killed in a fire on the (now-closed) Kenilworth Dump, in Washington, D.C. [H.R. Report No. 94-1491, 1976].

The potential harm that these hazards pose to facility personnel can be controlled through [44 FR 53460, September 13, 1979]:

- Proper training,
- Use of safety equipment,
- Control of waste types, and
- Other procedures.

However, these controls cannot be imposed upon the general public. The only way to prevent potential harm to the public is through prohibition of access to MSWLFs by non-users and strict control of users on the site [44 FR 53460, September 13, 1979].

In addition to the hazards that uncontrolled access at MSWLFs pose to human health and safety, access restrictions also serve to minimize illegal waste dumping at these facilities. The potential for illegal dumping of Subtitle C regulated hazardous wastes will increase as a result of the increasing stringency of the Subtitle C regulations. In the revised Criteria EPA specifically requires MSWLF owners and operators to "control public access and to prevent unauthorized vehicular traffic and illegal dumping of wastes" in municipal solid waste landfills by using artificial barriers, natural barriers, or both, as appropriate to protect human health and the environment.

In developing an access standard, the EPA reviewed the RCRA Subtitle C Standards as a means of formulating a consistent basis for access controls. Under Subtitle C owners or operators must prevent the unknowing entry, and minimize the possibility for the unauthorized entry, onto the active portions of the facility. At a minimum, such a hazardous waste facility must have a 24-hour surveillance system or an artificial or natural barrier, such as, a fence in good repair or a fence in combination with a cliff which completely surrounds the active portion of the facility and a means to control entry at all times. The requirements may be waived under Subtitle C if it can be demonstrated that physical contact with the waste or equipment will not injure unauthorized persons or livestock and disturbance of the waste or equipment will not threaten human health and the environment.

EPA considered the same strict standard for access control for Subtitle D; however, this alternative was rejected because the Subtitle C access requirements were considered somewhat too restrictive for MSWLFs because it would severely strain the practicable capability of the regulated community and because the hazards posed by direct contact with municipal solid wastes are less than those associated with hazardous waste. The standard selected, however, is similar to the Subtitle C requirements except that it allows greater consideration of site-specific conditions in establishing the appropriate controls. For example the remoteness of a site may serve as an adequate "natural barrier" to facility access. EPA believes that the requirement to control public access is flexible enough to allow owners or operators to implement a system designed for their facility based on site-specific characteristics.

The use of fencing or natural barriers is a common MSWLF engineering practice [Noble, 1986; Weiss, 1984; Brunner and Keller, 1972]. Fences or natural barriers act to control unauthorized and unintentional access to the site by scavengers, vandals, children, and animals. The majority of States and territories (35) already have requirements for perimeter barriers such as fences, locked gates, or topographic restraints [PEI, 1986].

EPA is establishing a performance oriented requirement that would allow access control systems to be designed on the basis of site specific characteristics. Access to MSWLFs and the potential harm to human health and the environment can be prevented through the use of artifical (man-made) controls, and/or natural controls. Artificial controls include gates and fences, while natural controls include trees, hedges, berms, ditches, cliffs, ravines, and embankments associated with railroads and roadways. In certain remote areas, the distance of the MSWLF from roadways may adequately serve to control access [EPA, SW-828, 1980].

Control of authorized persons on MSWLF sites can be achieved through any of the following measures [EPA, SW-828, 1980]:

- Supervision of the unloading area,
- Adequate lighting,
- Posting information and direction signs,
- Prohibition of scavenging, and
- Control of salvaging.

EPA believes that the requirements will control entry to MSWLFs and minimize exposure of the public to the health and safety hazards at MSWLFs. They will also help to minimize illegal dumping.

EPA has chosen performance oriented requirements for access control, and has left it to the States and MSWLF owners and operators to determine if specific design and operation requirements are necessary. For example, enclosure of MSWLFs by a 6 foot fence topped with barbed wire at a 45 degree angle is a common engineering practice at MSWLFs [Brunner and Keller, 1980; Weiss, 1974]. However EPA believes that this requirement is too inflexible and that adequate protection to human health and the environment can be afforded through natural as well as man- made barriers. EPA also reviewed the specifications for the visibility distance of signs posted at the boundary to hazardous waste landfills (25 feet) as prescribed in 40 CFR 265.14(c). However, requirements for the quantity, location, and visibility of signs at MSWLFs have been left to the States and MSWLF owners and operators. Several of the access controls required by the States and territories are presented in Attachment 9 in Appendix A.

H. RUN-ON/RUN-OFF CONTROL

EPA's revisions to the Subtitle D Criteria are based on the concept that liquids that may enter wastes, and thereby generate leachate, should be reduced. To accomplish this, the three methods by which liquids may enter wastes--(1) infiltration of precipitation, (2) introduction of liquid wastes, and (3) run-on of liquids from surrounding areas onto the active area of the unit--must be controlled. Furthermore, it is necessary to control run-off of liquids from active portions of a unit, because of the danger that the run-off will contaminate surface water.

Although the introduction of liquids is a concern for all phases of landfill operation, the active portion of landfills is of primary concern, due to irregular contours which promote infiltration and exposure of waste. Other areas of landfill operations are of less concern, since these have been closed, covered, and vegetated, thereby immobilizing or diverting any water near the surface.

Run-On

Two methods of minimizing run-on onto the active portion of landfills are (1) to make the active portion relatively impervious to water [Lutton, 1982; McAneny, 1985] or (2) to divert the water away from the active area [Weiss, 1974]. The first method is considered to be impractical because it would require measures comparable to those employed at the time of closure, and because it could not be implemented quickly enough to be effective, due to relatively rapid changes in the active area. The second method, run-on diversion, is accomplished either by using natural contours, or by constructing conveyances that are designed on the basis of the amount of water and potential damage that may occur as a result of a particular storm event.

Because storms vary in intensity and duration, it is possible to underdesign the diversion system (resulting in inadequate control), or to overdesign it (resulting in unnecessary and costly controls). To contend with the variability of storm events, EPA has chosen as the design parameter for run-on control the peak discharge of a storm whose intensity and duration is likely to occur once every 25 years. The Agency has adopted this approach to be consistent with the standards at 40 CFR Part 264 that require active portions of a hazardous waste landfill be protected from the peak discharge of a 25 year storm.

Run-Off

While run-on controls protect the active portions of landfills from most water, they do not prevent the introduction of direct rainfall. Since run-off resulting from direct rainfall from the active portions could be contaminated, it must not be allowed to leave the site unless applicable provisions of the Clean Water Act (CWA) are met. These provisions, as specified in existing regulation, prohibit discharge that violates Section 402 of the CWA, and non-point source pollution that violates a water quality management plan under Section 208 of the CWA.

EPA has chosen the peak discharge of a 25-year storm as the design parameter for run-off control for the same reasons (discussed above) that the Agency chose this parameter for run-on control. For run-off control, however, one must take into

consideration the volume of water to be collected, since water in contact with wastes in the active area may be collected together with uncontaminated run-off. The volume of water precipitated during a 24-hour period is usually the measure used in storm water management design for small watersheds of less than 2000 acres [SCS, Engineering Division, 1975; Viessman et al., 1977]. This 24-hour period is an average which includes storms of high intensity with short duration and storms of low intensity with long duration.

Control Measures

As outlined above, the owner or operator must prevent the flow of surface water onto the active portion of an MSWLF during the peak discharge from a 25-year storm. The owner or operator must also collect and control, at a minimum, the surface water volume from the landfill's active portion that would result from a 24-hour, 25-year storm, so that no discharges violate provisions of the CWA.

Three types of control measures should be implemented to comply with the above requirements:

1) Diversion of surface water run-off by interception and conveyance from off-site areas to stable outlets at non-erosive velocities, to prevent surface water run-on to the MSWLF active face is the first type of control measure. If diversion does not occur naturally, then diversion controls must be constructed. The design of diversion drainage ways is best accomplished by using the following equation (Rational Formula):

$Qp = CIA$

where:

Qp = the peak run-off rate (cubic feet per second)
C = the run-off coefficient (dimensionless)
I = the average rainfall intensity (in./hr.), lasting for a critical time period, t_c
t_c = the time of concentration
A = the size of the drainage area (acres)

The Rational method is described in any basic hydrology text (e.g., Viessman et al.). Once the peak run-off rate is known, diversion drainage ways with the capacity to divert the run-off without eroding soils can be incorporated into the landfill design. The U.S. Soil Conservation Service Technical Release No. 55, Urban Hydrology for Small Watersheds [SCS, Engineering Division, 1975], provides information that is useful in quantifying the peak run-off rate through the use of the rational method, and in designing conveyances using the following equation (Manning Formula):

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

Where:

Q = flow quantity (cu. ft. per sec.)
n = roughness coefficient
A = cross-sectional area of flow (sq. ft.)
R = hydrauic radius (ft.)
S = slope (ft. per ft.)

Detailed application of the Manning Formula can be found in drainage design manuals, such as the American Iron and Steel Institute's Modern Sewer Design [American Iron and Steel Institute, 1980]. Local focus for the quantification of peak run-off rate and the design of conveyances can be found in State and county documents. Site-specific information needed to use the design equation, such as the size of drainage area for the rational formula and slopes for the Manning Formula, will require site-specific surveys.

2) Collection of run-off from the active portion of MSWLFs is the second type of control measure. When the area of the active face is known, and the amount of rainfall occurring over a 24-hour period from a 25-year storm is calculated (found in U.S. Soil Conservation Service, TR-55), then the design volume for storage can be determined. Additional storage capacity, also must be provided, because soil and waste would likely be washed away from the active face, partially filling available volume.

Emergency storage equal to the 24-hour, 25-year storm volume must be provided as well, in the event that design volume is already filled when such a storm occurs. Storage is best accomplished by using a waste storage pond, as described in the National Handbook of Conservation Practices [SCS, 1977], or by using a modified sediment basin, as described in design manuals for State or county standards and specifications for soil erosion and sediment control. Storage ponds or basins may include a liner to contain collected contaminated run-off, if the storage basin soil is relatively permeable. Diversion, as described above, must be designed around the active face to convey contaminated run-off to the storage structure.

3) Treatment of collected contaminated run-off is a third type of control measure. Because the analyses of collected run-off may be required before one can determine that the CWA would not be violated upon discharge, it may be easier to manage all collected run-off as contaminated. Treatment for contaminated run-off is the same as that for leachate collected elsewhere at the landfill. Therefore, at large landfills, it may be feasible to construct a dual leachate/contaminated run-off collection and treatment system.

I. SURFACE WATER

The proper design and operation of MSWLFs are necessary to ensure that landfill activities do not adversely impact the surface waters of the United States. EPA has identified two major pathways of contamination of surface water from MSWLFs. These are point source discharges, and non-point source discharges, and subsurface migration.

Point source discharges from MSWLFs include [EPA, SW-828, 1980]:

- A discharge from a leachate collection system into waters of the United States, including leachate from discrete channels or fissures,

- A discharge from an on-site leachate treatment system directly into waters of the United States. Leachate that is conveyed to off-site treatment facilities (e.g., sewage treatment plants) is not considered as a point source discharge from the facility, and

- A discharge of surface run-off that is collected or channeled by man.

Non-point source discharges of pollutants from MSWLFs consist of all surface run-off from MSWLFs that is not collected or channeled by man [44 FR 53444, September 13, 1979].

Section 1006 of RCRA requires EPA to integrate, to the maximum extent practicable, the provisions of RCRA with the Clean Water Act (CWA) and other statutes [44 FR 53444, September 13, 1979]. Because the legislative authority for protection of waters of the United States resides with the CWA, the current Part 257 Criteria were written to reference and incorporate the authority and regulatory mechanisms of the CWA and did not create new regulations [EPA, Background Document: Surface Water, 1979]. EPA believes that the requirements of the CWA, including but not limited to Section 402 which creates the National Pollution Discharge Elimination System (NPDES), adequately protect surface waters from adverse impacts due to point source discharges from MSWLFs. Section 208 of the CWA, that authorizes the development of area-wide or State-wide water quality management plans, provides adequate protection from non-point source pollution. The Agency, therefore, has retained this provision in the revised Criteria.

J. LIQUIDS RESTRICTIONS

The primary goal of the revisions to the Subtitle D Criteria is to prevent ground-water contamination at MSWLFs that will threaten human health and the environment. to accomplish this goal it is necessary to control the generation and migration of leachate. Leachate is produced when liquids, introduced into a landfill either naturally (e.g., rainfall) or artificially (e.g., disposal of liquids), percolates through the landfill dissolving and mobilizing various soluble components of the wastes (Lu et al, 1985). Leachate contains a broad range of organic and inorganic constituents that may adversely impact ground water. (See Attachments 12 and 13,

Appendix A). The revised Criteria, therefore, include provisions that require owners and operators to minimize and control the amount of liquids that may come in contact with the wastes. These provisions address run-on and run-off controls (see Section III.H of this report), design criteria for final covers (see Background Document on Design Criteria [EPA, 1988]), and liquids management (addressed in this Section).

In an effort to reduce the amount of leachate generated, EPA is adopting a policy of restricting the introduction of liquids into landfills. By restricting the introduction of liquids into landfills through a ban on the disposal of bulk and containerized liquids, EPA expects to minimize the leachate generation potential of the landfill, and thus minimize the risk of ground-water contamination. Forty-eight percent of MSWLFs already employ some type of restrictions on the receipt of liquid wastes [EPA, 530-SW-86-054, 1986], and 21 States and territories prohibit disposal of liquid and semi-liquid wastes in MSWLFs altogether [PEI, 1986].

The problems associated with the landfill disposal of containerized liquid wastes arise upon the eventual deterioration of the waste container. Liquids escaping from leaking containers will migrate to the bottom of the landfill, acting as a transport and leaching medium for the wastes contained in the landfill [45 FR 33212, May 19, 1980]. Liquids accumulating on landfill liners can contribute to liner failure through increased hydraulic pressure and/or chemical interactions. Increased hydraulic head due to liquid accumulation can increase the amount and rate of contaminant movement from the landfill to the ground water [GCA, 1986]. Additionally, when waste containers degrade, allowing their contents to escape, they collapse under the pressure of the landfill, creating voids in the landfill, that can lead to slumping and subsidence of the final cover. Once the integrity of the landfill cover is compromised, infiltration of precipitation will increase, contributing to the leachate generation problem in the landfill [47 FR 8307, February 25, 1982]. Generally, collapse of deteriorated waste containers and subsequent damage to the cover material occur after the post-closure care period of the landfill, when leachate collection systems and ground-water monitoring systems are not maintained to prevent or detect ground-water contamination. Another factor that EPA considered in its decision to ban disposal of containerized liquids in landfills is that:

> in most cases, leaking containers will release liquids slowly over time. This typically means that leachate within the facility will rain down on the facility liner at a relatively slow rate. Where the liner is constructed of a relatively permeable material (e.g., clay), this low rate of leachate impingement will mean that a significant percentage of the leachate will exfiltrate through the liner rather than flow along the top of the liner to points where it can be collected and removed [47 FR 8311, February 25, 1982].

Disposal of bulk or non-containerized liquids in landfills present the same problems that disposal of containerized liquids present once they have leaked from their containers, namely, increased mobility of wastes in the landfill, increased risk of loss of liner integrity through greater pressure and/or chemical interactions, and increased hydraulic head that can increase the rate and quantity of movement of contaminants to the ground water.

EPA believes that the liquids management criteria selected address the problems associated with disposal of liquids in landfills. The ban on the disposal of bulk or non-containerized liquids (except those from households and recirculated leachate and gas condensate at facilities with specific designs) will greatly reduce the quantity of free liquids managed in MSWLFs, that in turn will reduce the risk of liner failure and subsequent contamination of the ground water. The ban on containerized free liquids (except those from households) will achieve the same purposes as the ban on bulk liquids, and in addition, it will reduce the problem of subsidence and possible damage to the final cover upon eventual deterioration of the waste containers. Very small containers and containers designed to hold free liquids for use other than storage (such as batteries and capacitors) are exempt from the containerized liquids ban because "these types of containers are not likely to contribute substantial amounts of liquids to most landfills, and the difficulty of opening and emptying them appears to outweigh the small benefit gained" [45 FR 33215, May 19, 1980].

The liquids ban does not include leachate and gas condensate recirculation at MSWLF units that incorporate a composite liner and leachate collection system into their design. Studies have indicated that leachate recirculation has certain benefits,

that include, increasing the rates of waste stabilization, improving leachate quality, and increasing the quantity and quality of methane gas production. Leachate recirculation also provides a viable on-site leachate treatment method. Recent studies conducted by EPA indicate that of those facilities collecting leachate (481 MSWLFs; 5% of total), forty-two percent (205 MSWLFs) are recirculating leachate. The Agency expects that the number of MSWLFs collecting leachate will increase with the implementation of the proposed design criteria prescribed under Subpart D of the Criteria.

However, there are potential operational problems associated with leachate and gas condensate recirculation that may result in adverse impacts on human health and the environment. These problems include: (1) the increase in leachate production, (2) clogging of the leachate collection system, (3) build-up of hydraulic static head within the unit, (4) increase in air pollutant and odor problems, and (5) increase in the potential of leachate pollutant releases due to drift and/or run-off [Pickard and Anderson, 1985]. Therefore, EPA is proposing that only MSWLF units designed and equipped with composite liners and a leachate collection system constructed to maintain less than 30-cm depth of leachate over the liner will be allowed to recirculate leachate and gas condensate.

Because of the increased leachate generation and subsequent hydraulic head build-up, EPA believes that the added protection provided by a composite liner is necessary to ensure that contaminant migration to the aquifer is controlled. A composite liner is a system comprised of two components; the upper component must consist of a flexible membrane liner (FML), the lower component is comprised of at least a three (3) foot layer of compacted soil with a hydraulic conductivity of no more than 1×10^{-7} cm/sec. The FML component must be installed in direct and uniform contact with the compacted soil component so as to minimize the migration of leachate through the FML if a break should occur.

First, the FML portion of the liner will increase leachate collection efficiency and provide a more effective hydraulic barrier. Second, the soil portion will provide support to the FML and the leachate collection system, and acts as back-up in the event of failure of the FML.

The standard for the leachate collection system, constructed to maintain less than 30 cm of leachate over the liner, is the same standard required for LCSs at Subtitle C hazardous waste units and various technologies are available for meeting this requirement. The appropriate technology is based on the size of the unit, waste permeability, and climatic conditions. LCS design normally consists of a permeable material placed on a sloping surface so as to allow the leachate to be removed and collected. For large units, a tile drainage system also may be necessary.

There are other methods for managing leachate besides recirculation. These include disposal in off-site POTWs or the construction of on-site treatment facilities. Onsite treatment facilities and POTWs generally employ biological methods for primary treatment, and use physical/chemical processes if secondary treatment is required. Attachment 14 in Appendix A describes the process performances of various biological and physical/chemical treatment methods. Studies have shown that biological processes such as activated sludge, aerated lagoons, or stabilization ponds can remove 90 to 95 percent of the organics and metals leached from landfill waste [Pohland and Harper, 1986].

Activated sludge is the most common treatment method employed at POTWs. However, the low capital investment requirements of aerated lagoons and stabilization ponds may make them the most appropriate methods for onsite treatment. The process performances and design parameters for aerated lagoons and stabilization ponds are presented in Attachments 15 and 16, respectively, in Appendix A.

Inorganic treatment methods are generally employed as secondary or polishing treatment methods. Secondary treatment may be necessary to meet the requirements of an NPDES permit. Common inorganic treatment methods include coagulation/precipitation, oxidation, reverse osmosis, ion exchange, and activated carbon adsorption. The process performances of these treatment methods are presented in Attachment 14 in Appendix A. Attachment 17 (Appendix A) describes the inorganic treatment processes that have been used at several leachate treatment facilities.

The Paint Filter Test, the same test used by the Subtitle C hazardous waste program, has been selected as the method for determining whether the waste is a liquid waste prior to disposal in a MSWLF. In choosing this test method for its hazardous waste program, EPA considered over 70 test procedures including gravity tests and tests that simulate earth pressures at various depths. The Agency believes that physical processes of liquid-solid separation are the same for both hazardous and non-hazardous wastes, and therefore, believes this an appropriate method to be used for MSWLF waste.

EPA considered banning the disposal of all free liquids in MSWLFs, including liquid waste from households. Although banning all liquid disposal in MSWLFs, no matter what the source, would provide maximum benefits to human health and the environment, it was felt that such regulations that would probably require waste classification and separation at the household level, would be impossible to implement and would be beyond the practicable capability of the regulated community. Therefore, EPA chose to exempt household wastes from the liquids ban.

The regulatory history to 40 CFR 264.314 and 265.314 (restrictions on the disposal of free liquids in hazardous waste landfills) contains commentary that was useful in evaluating liquids restriction requirements for MSWLFs. While hazardous and nonhazardous wastes pose different risks to human health and the environment, the physical and chemical processes of leachate generation and movement are similar and in many cases identical. Commenters to the hazardous waste regulations promulgated on May 19, 1980 suggested that free liquids in hazardous waste landfills would be absorbed by the surrounding refuse. Indeed, in its May 19, 1980 rulemaking EPA allowed in-situ absorption of free liquids in hazardous waste landfills "provided the landfill has a chemically and physically resistant liner and a functioning leachate removal system, and provided the capacity to remove the hydraulic head is not exceeded" [45 FR 33212, May 19, 1980]. However, in this same preamble, EPA states that:

> when liquid wastes are disposed of directly into a landfill without assuring absorption, there is no way of knowing whether they are largely being absorbed and held by solids in the landfill, or are passing through relatively quickly. Liquid migration can, however, be greatly

reduced if liquid wastes and wastes containing free liquids are treated before being landfilled, as by mixing with absorbent materials, so that free liquids are no longer present [45 FR 33215, May 19, 1980].

Subsequent to the HSWA amendments to RCRA in November 1984, the placement of bulk or non-containerized liquids in hazardous waste landfills has been prohibited, regardless of whether absorbents have been added [50 FR 28704, July 15, 1985].

Several regulatory options were also considered before the Agency decided to exempt leachate and gas condensate recirculation at MSWLFs with specific design features from the liquids ban. The options that EPA considered are presented in Attachment 18 in Appendix A. These options ranged from allowing leachate recirculation as a full scale method of leachate treatment at all landfills (regardless of whether or not they have a leachate collection system) to a ban on leachate recirculation as a leachate treatment method at all new landfills and at existing facilities after a 5 year period.

K. RECORDKEEPING

The maintenance of comprehensive records of operation at MSWLFs is necessary to ensure that the MSWLF is designed and operated in compliance with all the requirements set forth in the Criteria. Complete facility operating records will ensure that proper procedures are followed for ground-water sampling, statistical analysis of the sampling data, and notification of property owners of potential adverse impacts to the ground water underlying their property. Maintenance of sampling data for the monitoring of explosive gases in facility structures and at the facility boundary will ensure that the risk of fires and explosions due to the accumulation of explosive gases is minimized.

Facility operating records might also serve to provide a data source for future evaluations of MSWLF criteria at the Federal, State, and local levels. The operating records could provide empirical verification that a facility's assigned location category provides adequate protection to human health and the environment for that particular geographic area This information could be useful to States and

localities in future siting of MSWLFs in the same area. The records required under this part will provide a documentation of facility operation that could be useful in settling citizen complaints or adjudicating damage claims resulting from operation of MSWLFs.

EPA has not specified the use of particular forms or procedures for maintaining the records required nor have reporting requirements been prescribed. This allows States and localities to continue to use existing forms and procedures, providing that they document all the information required in this section.

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APPENDIX A.

ATTACHMENTS FOR SECTION III

TABLE 4-5. OPERATIONAL COVER REQUIREMENTS

State	Daily	48 h	Three times/week	Twice/ week	96 hours	7 days	14 days	Twice/ month	Monthly	Determined by agency	6-in. depth
Alabama	x					x[c]					x
Alaska	x[d]		x[e]	x[f]		x[g]		x[h]	x[i]		
Alaska[b]	x[d]		x[e]	x[f]		x[g]		x[h]			
Arizona	x			x[j]		x[k]	x[l]				x
Arkansas	x										x
California	x[m]	x[n]			x[o]					x[p]	x
Colorado	x										x
Connecticut	x										x
Delaware	x										x
Dist. of Col.[a]											
Florida	x[q]				x[r]	x[c]					x
Georgia	x										x
Hawaii	x										
Idaho	x										x
Illinois	x										x
Indiana	x										x
Iowa	x					x[c]					x
Kansas											
Kentucky	x										x
Louisiana	x										x
Maine	x										
Maryland[b]	x										x
Maryland	x										x
Massachusetts[b]	x										
Massachusetts	x										x
Michigan	x										x
Minnesota	x										x
Mississippi	x										x
Missouri	x										x
Montana	x										x
Nebraska											x
Nevada	x				x[j]	x[s]					x
New Hampshire	x										x

(continued)

Attachment 1
(Source: PEI, 1986)

TABLE 4-5 (continued)

State	Daily	48 h	Three times/week	Twice/ week	96 hours	7 days	14 days	Twice/ month	Monthly	Determined by agency	6-in. depth
New Jersey	x										x
New Mexico	x										x
New York	x										x
North Carolina	x										x
North Dakota	x										x
Ohio	x										x
Oklahoma	x										x
Oregon											
Pennsylvania											x
Rhode Island	x										x
South Carolina	x										x
South Dakota	x										
Tennessee	x					x[u]			x[v]	x[c]	x
Texas	x[t]										x
Utah	x										x
Vermont	x										x
Virginia	x										x
Washington	x										x
West Virginia	x										
Wisconsin	x										x
Wyoming	x[w]					x[x]			x[c,y]		x
Am. Samoa											
Guam	x										x
N. Mariana Is.[b]	x										
Puerto Rico											
Virgin Is.											

(continued)

Attachment 1
(Cont.)

TABLE 4-5 (continued)

[a] Information not received.
[b] Proposed regulations.
[c] Only inert non-putrescibles.
[d] Greater than 20 tons/day or serves greater than 2,000 people.
[e] 5,000 to 10,000 lb/day or 1,000 to 2,000 people.
[f] 3,750 to 5,000 lb/day or 750 to 1,000 people.
[g] Less than 12.5 tons/day or 400 to 750 people.
[h] 1,000 to 2,000 lb/day or 200 to 400 people.
[i] Less than 3.75 tons/day or less than 200 people.
[j] 1,000 to 2,000 people.
[k] 500 to 1,000 people.
[l] Less than 500 people.
[m] Greater than 50 tons/day.
[n] 5 to 50 tons/day.
[o] 1 to 5 tons/day.
[p] Less than 1 ton/day.
[q] Greater than 20 tons/day or 50 yd^3.
[r] Less than 20 tons/day or 50 yd^3.
[s] Less than 1,000 people.
[t] Greater than 5,000 people.
[u] Less than 5,000 people.
[v] Less than 3.75 tons/day or less than 1500 people.
[w] Greater than 2,100 tons/yr or greater than 3,000 people.
[x] 1,000 to 3,000 people.
[y] Less than 1,000 people.

Attachment 1
(Cont.)

TABLE 4-6. INTERMEDIATE COVER AND COVER MATERIAL SPECIFICATIONS

State	Intermediate cover: Period of inactivity (days) 1	7	14	30	60	90	120	180	220	365	Depth: 12 inch Minimum depth	Cover specifications: Good compactibility	Resists cracking	Adequate seal	Excluded materials: Putrescible mat'l	Free liquids	Toxic materials
[illegible]ama						x					x	x		x			
Alaska[b]				x													
A[illegible]ka				x													
Arizona																	
Arkansas					x						x						
California								x			x			x	x		
Colorado				x							x						
Connecticut									x		x						
Delaware										x		x	x		x		
Dist. of Col.[a]																	
Florida								x			x						
Georgia											x						
Hawaii																	
Idaho										x	x	x	x		x		
Illinois					x						x	x					
Indiana																	
Iowa		x									x						
Kansas																	
Kentucky					x						x						
Louisiana																	
Maine																	
Maryland[b]					x						x	x			x	x	x
Maryland[b]												x		x	x		
Massachusetts[b]					x						x	x		x	x		
Massachusetts[b]						x					x						
Michigan							x				x						
Minnesota											x	x		x			
Mississippi				x							x						
Missouri						x					x						
Montana																	
Nebraska																	
Nevada	x										x				x		
New Hampshire				x							x						

(continued)

Attachment 2
(Source: PEI, 1986)

TABLE 4-6 (continued)

State	Intermediate cover: Period of inactivity (days) 1	7	14	30	60	90	120	180	220	365	Intermediate cover: Depth 12 inch Minimum depth	Cover specifications: Good compactibility	Resists cracking	Adequate seal	Excluded materials: Putrescible mat'l	Free liquids	Toxic materials
New Jersey								x									
New Mexico											x						
New York				x							x						
North Carolina										x	x						
North Dakota																	
Ohio				x							x	x					
Oklahoma			x								x				x		
Oregon															x		
Pennsylvania										x	x						
Rhode Island								x			x						
South Carolina				x							x						
South Dakota																	
Tennessee				x							x						
Texas																	
Utah																	
Vermont											x						
Virginia																	
Washington																	
West Virginia																	
Wisconsin																	
Wyoming																	
Am. Samoa		x[c]								x[c]	x	x					
Guam																	
N. Mariana Is.[b]								x									
Puerto Rico																	
Virgin Is.																	

(continued)

Attachment 2
(Cont.)

TABLE 4-6 (continued)

State	Cover specifications						
		Preventative properties				Quantity	
	Emergence of flies, rodents	Blowing litter	Progress of fires	Escape of odors	Excess water infiltration	Sufficient quantities	Specific limits
Alabama							
Alaska							
Arizona							
Arkansas	x	x	x	x	x		
California	x		x	x	x	x	
Colorado							
Connecticut							x
Delaware					x		
Dist. of Col.[a]							
Florida							
Georgia							
Hawaii							
Idaho			x				
Illinois							x
Indiana							
Iowa							
Kansas							
Kentucky						x	
Louisiana							
Maine							
Maryland[b]				x	x		
Maryland	x			x		x	
Massachusetts[b]	x						x
Massachusetts	x						x
Michigan							
Minnesota						x	
Mississippi							
Missouri	x	x	x	x	x		
Montana							
Nebraska							
Nevada	x					x	
New Hampshire						x	

(continued)

Attachment 2
(Cont.)

TABLE 4-6 (continued)

State	Emergence of flies, rodents	Cover specifications: Preventative properties: Blowing litter	Preventative properties: Progress of fires	Preventative properties: Escape of odors	Preventative properties: Excess water infiltration	Quantity: Sufficient quantities	Quantity: Specific limits
New Jersey							
New Mexico					x		
New York						x	
North Carolina						x	
North Dakota							
Ohio							
Oklahoma						x	
Oregon							
Pennsylvania							x
Rhode Island							
South Carolina							
South Dakota							
Tennessee							
Texas							
Utah							
Vermont							
Virginia						x	
Washington							
West Virginia						x	
Wisconsin							
Wyoming							
A. Samoa							
Guam	x	x	x	x	x	x	
N. Mariana Is.[b]							
Puerto Rico	x						
Virgin Is.[a]							

[a] Information not received

[b] Proposed regulations.

[c] Varies from one week to one year.

Attachment 2
(Cont.)

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December 11, 1985
File No. 28286-19, LC 93

Mr. Allen Geswein
Land Disposal Branch
Office of Solid Waste
U.S. Environmental Protection Agency
401 M Street SouthWest
Washington, DC 20460

Subject: Trace Contaminants in Landfill Gas

Dear Al:

At the Landfill Gas (LFG) workshop held on October 10, Bob Stearns indicated that we could provide you with data regarding LFG characterization (trace constituents). We were unable to use the source of data to which Bob had referred. Instead, we compiled LFG trace constituent data from our files.

Table 1 is a compilation of analyses of LFG samples from 16 landfills throughout the nation. All of the analyses were conducted in 1984 and 1985, except for one in 1981 and one in 1983. The samples were collected from passive vents or from blowers exhausting LFG except for two sites where the samples were collected from crevices with significant LFG emissions.

All sites from which samples were collected were municipal solid waste landfills. Some were thought to contain small percentages of hazardous waste (in addition to household hazardous wastes). However, municipal solid waste was overwhelmingly predominant at all sites.

Between one and seven samples from each site were collected and analyzed. Eight different laboratories performed the analyses. The 62 constituents listed in Table 1 were analyzed for three or more times, and 61 were found at least once. Table 2 is a list of constituents that were reported only one or two times. The constituents on Table 2 are thought to be aberrations rather than typical trace constituents.

Table 3 lists the 14 constituents that were found at least five times. Currently, we feel that these 14 constituents typify trace contaminants in LFG.

Both mean and median concentrations are noted in Table 1. The median values generally are much lower than the mean values; a single, relatively high reading for a number of the constituents caused the mean values to be higher than the results of the majority of the analyses. Accordingly, it is thought that the median values more accurately reflect of typical trace contaminants in LFG.

Table 3 also notes the U.S. Occupational Safety and Health Administration's (OSHA) Permissible Exposure Level (PEL) for the 12 constituents for which PELs have been established. As can be seen in this Table, the maximum concentration of only five constituents reported in this data base exceeded the PEL, which is the time-weighted average 8-hour-per-day, 40-day-per-week permissible level of exposure in the work place. Only vinyl chloride had a median concentration in excess of its PEL.

Although the data show that concentrations of several trace constituents have been found to exceed their PELs, we feel that, in general, LFG emissions to the atmosphere do not constitute a health hazard even to infants and infirm people. This is due to what might be described as a two-stage dilution. LFG is almost instantaneously diluted as it is emitted into the atmosphere (probably by an order of magnitude). Further dilution occurs as the gas moves toward human receptors off-site. This dilution is normally several orders of magnitude.

Please feel free to contact me if you have any questions regarding this information. We would be glad to meet with you to further explain or discuss this information.

Very truly yours,

Tom

E. T. Conrad, PE
Principal
SCS ENGINEERS

ETC:jwg

enclosure

cc: B. Stearns
J. Walsh

TABLE 1. TRACE CONSTITUENTS FOUND IN LANDFILL GAS (Concentrations Given in PPM)

Compound	EPA Number	Number of Sites Sampled	Number of Sites Detected	Number of Samples	Number of Detections	Range of Concentration	Mean Concentration	Median Concentration	Standard Deviation
Acetone		6	3	6	3	0.048 - 2	.4	0.02	0.8
Benzene	U019	13	8	21	14	0 - 12	1.4	0.3	3.0
Butane		3	3	3	3	1.0 - 44	17	5.6	24
Carbon disulfide	P022	5	1	5	1	0 - 3.1	0.6	0	1.4
Chlorobenzene	U037	5	1	5	1	0 - 0.29	0.1	0	0.1
Cyclohexane	U056	6	4	7	4	0 - 27	4.3	0.02	10
Decane		4	2	4	2	0 - 0.092	0.03	0.02	0.04
1,2-Dichlorobenzene	U070	3	2	4	2	0 - 0.34	0.1	0	0.2
1,2-Dichloroethane	U077	7	3	8	3	0 - 11	3.1	0	4.2
1,1-Dichloroethylene	U078	6	2	7	2	0 - 1.1	0.2	0	0.4
Dimethylcyclohexane		3	3	3	3	0.032 - 0.13	0.1	0.03	0.1
Dimethyl Decane		3	1	3	1	0 - 0.13	0.04	0	0.08
Dimethyl Heptane		3	3	4	3	0 - 0.4	0.1	0.02	0.2
Dimethyl Hexane		4	3	5	3	0 - 1.8	0.4	0.01	0.8
Dimethyl Octane		3	3	3	3	0.024 - 0.53	0.2	0.03	0.3
Dimethyl Pentane		4	3	4	3	0 - 5.6	1.7	0.5	2.7
Ethanol		3	3	3	3	0.4 - 12	4.9	2.2	6.2
Ethylbenzene		1	9	14	12	0 - 91	12	1.5	24
Ethyl Cyclohexane		3	3	3	3	0.029 - 28	9.4	0.04	16
Ethyl Methyl Benzene		4	2	4	2	0 - 1.9	0.5	0.001	0.9
Ethyl Methyl Cyclohexane		3	3	3	3	0.06 - 0.45	0.2	0.09	0.2
Ethyl Methyl Cyclopentane		3	1	3	1	0 - 0.03	0.01	0	0.02
Ethyl Methyl Decane		3	3	3	3	0.028 - 0.07	0.05	0.05	0.02
Heptane		4	4	6	5	0 - 11	3.8	0.45	5.2
Hexane		8	6	9	7	0 - 31	7.1	0.8	11
Isopentane		5	5	7	7	0.05 - 4.5	2.0	2.0	1.5
Methylcyclohexane		6	6	7	7	0.017 - 19	7.7	3.6	8.8
Methylcyclopentane		6	5	7	6	0 - 12	3.9	2.8	4.4
Methyl Decane		3	2	3	2	0 - 1.2	0.4	0.07	0.7
Methylene Chloride	U080	10	6	17	13	0 - 118	13	0.83	30
Methyl Ethyl Ketone	U159	8	3	9	4	0 - 26	4.3	0	8.5
Methyl Heptane		4	3	5	3	0 - 6.5	1.4	0.03	2.8
Methyl Hexane		3	3	4	3	0 - 1.4	0.4	0.004	0.7
Methyl (Methylethenyl) Cyclohexane		3	2	3	2	0 - 0.21	0.1	0.02	0.1
Methyl Nonane		4	3	4	3	0 - 0.54	0.2	0.05	0.3
Methyl Octane		4	3	4	3	0 - 0.96	0.3	0.04	0.5
Methyl Pentane		5	2	5	2	0 - 12	2.4	0	5.4
Methyl Undecane		3	3	3	3	0.011 - 0.11	0.04	0.01	0.06

Attachment 3 (Cont.)

TABLE 1. (continued)

Compound	EPA Number	Number of Sites Sampled	Number of Sites Detected	Number of Samples	Number of Detections	Range of Concentration	Mean Concentration	Median Concentration	Standard Deviation
Napthalene	U165	3	2	4	2	0 - 0.99	0.3	0.02	0.5
Nonane		6	5	8	7	0 - 24	4	0.54	8.2
Octane		4	3	5	4	0 - 23	8.6	5	8.8
n-Octane		3	2	4	2	0 - 0.5	0.2	0.06	0.2
Pentane		3	1	3	1	0 - 6.4	2.1	0	3.7
Propyl Cyclohexane		3	2	3	2	0 - 0.84	0.3	0.07	0.5
Styrene		8	0	8	0	0	0	0	---
Tetrachloroethylene	U210		13	9	19	13 0 - 186	17	0.03	44
Tetrahydrofuran	U213	5	1	5	1	0 - 8.9	1.8	0	4.0
Tetramethyl Hexane		3	2	3	2	0 - 0.19	0.1	0.13	0.1
Toluene	U220	16	15	26	25	0 - 357	42	6.8	82
1,1,1,-Trichloroethane	U226	11	6	18	11	0 - 2.4	0.3	0.03	0.6
Trichloroethylene	U228	12	6	19	12	0 - 44	3.7	0.12	10
Trichlorofluoromethane	U121	5	1	5	1	0 - 8.8	1.8	0	3.9
Trimethyl Benzene		3	2	4	2	0 - 0.68	0.2	0.01	0.3
Trimethylcyclohexane		3	3	3	3	0.01 - 0.31	0.1	0.017	0.2
Trimethyl Decane		3	2	3	2	0 - 0.15	0.1	0.001	0.1
Trimethylhexane		3	3	3	3	0.005 - 0.18	0.07	0.03	0.09
Trimethyl Pentane		3	2	3	2	0 - 0.53	0.18	0.01	0.3
Undecane		4	2	4	2	0 - 0.97	0.2	0.01	0.5
Vinyl Chloride	U043	10	5	16	10	0 - 10	3.5	2.2	3.7
Xylene	U239	5	4	6	5	0 -111	29	0.1	48
m-Xylene	U239	4	4	9	9	1.7 - 76	19	4.1	28
o-Xylene	U239	7	6	9	8	0 - 19	5.6	1.8	7.7

Attachment 3
(Cont.)

TABLE 3. TYPICAL TRACE CONSTITUENTS IN LANDFILL GAS

Compound	Number of Sites Sampled	Number of Samples	Range of Concentration (Vppm)	Median Concentration (Vppm)	Standard Deviation (Vppm)	PEL* (Vppm)
Benzene	13	21	0 - 12	0.3	3.0	10 +
Ethylbenzene	11	14	0 - 91	1.5	24	100
Heptane	4	6	0 - 11	0.45	5.2	500
Hexane	8	9	0 - 31	0.8	11	500
Isopentane	5	7	0.05 - 4.5	2.0	1.5	---
Methylcyclohexane	6	7	0.017- 19	3.6	8.8	500
Methylcyclopentane	6	7	0 - 12	2.8	4.4	---
Methylene Chloride	10	17	0 -118	0.83	30	500
Nonane	6	8	0 - 24	0.54	8.2	400
Tetrachloroethylene	13	19	0 - 86	0.03	44	100
Toluene	16	26	0 -357	6.8	82	100
1,1,1-Trichloroethane	11	18	0 - 2.4	0.03	0.6	350
Trichloroethylene	12	19	0 - 44	0.12	10	100
Vinyl Chloride	10	16	0 - 10	2.2	3.7	1
Xylene	5	6	0 -111	0.1	48	100
m-Xylene	4	9	1.7 - 76	4.1	28	100
o-Xylene	7	9	0 - 19	1.8	7.7	100

* Permissible Exposure Level prescribed by OSHA for workplace exposure.
\+ OSHA has proposed revising the PEL for benzene to 1 Vppm.
--- No PEL set.

Attachment 3 (Cont.)

TABLE 2. TRACE CONSTITUENTS FOUND ONE OR TWO TIMES IN LANDFILL GAS

Compound	EPA Number	PEL (Vppm)	Number of Samples	Number of Detections	Detection Levels (Vppm)	(Vppm)
Acetic acid butyl ester			1	1	4.6	
Acetic acid propyl ester			1	1	14	
Alpha pinene			1	1	26	
Bis (methyl ethyl) benzene			1	1	0.1	
Butanoic acid butyl ester			2	2	4.6	2.7
Butanoic acid ethyl ester			2	2	54	17
Butanol	U031		2	2	3.2	16
Butene			2	2	8.0	6.0
Carbonochlorodiacid propylester			1	1	1.7	
Carbonyl sulfide			1	1	200	
Cyclopentanone			1	1	4.5	
Dichlorodifluoromethane	U075	1000	1	1	5.9	
Dimethylbutane			1	1	2.0	
Dimethylcyclopentane			1	1	8.3	
Dimethyl hexene			2	1	0.02	
Dimethyl nonane			2	2	0.04	0.02
Dimethyl octene			1	1	7.1	
Dimethyl sulfide			1	1	4.9	
Dimethyl undecane			1	1	0.32	
Ethyl acetate	U112	400	2	2	5.7	20
Ethylene			2	2	5.0	5.0
Ethyl ether	U117	400	1	1	1.5	
Ethyl hexanol			2	1	1.0	
Ethanol pentane			1	1	0.9	
Hexanol			1	1	0.42	
Hexene			1	1	36	
Isobutane			2	2	10	3.4
Iso-octanol			1	1		
Isopropyl alcohol		400	1	1	14	
Methylacetate		200	1	1	1.4	
Methylbutene			1	1	2.3	
(Methylethyl) benzene	U055		1	1	14	
Methylethyl cyclohexane			1	1	0.20	
Methyl isobutyl ketone	U161	100	1	1	1.9	
Methylpropane			2	1	26	
Methylpropyl benzene			1	1	0.43	
Nonanol			1	1	1.0	
Ortho toluene	U220	100	1	1	11	
Pentene			2	2	0.9	1.0
Pinene			1	1	2.0	
Propane		1000	2	2	13	1.0
Propanoic acid ethyl ester			2	2	13	3.5
Propanol		200	2	2	4.8	2.2
Propene			1	1	3.2	
Propylbenzene			1	1	2.1	

TABLE 2. (continued)

Compound	EPA Number	PEL (Vppm)	Number of Samples	Number of Detections	Detection Levels (Vppm)	(Vppm)
Propylene			1	1	2	
Propyl heptane			2	2	43	17
Propyl heptanol			1	1	28	
Sulphur dioxide		5	1	1	200	
Tetramethyl benzene			1	1	0.6	
Tetramethyl pentane			2	2	32	9.7
Thiobis methane			1	1	18	
Trichlorotrifluoroethane		1000	2	1	70	
Trimethylcyclopentane			1	1	4.5	
Trimethyl octane			1	1	25	

TABLE 1: LANDFILL GAS MIGRATION DAMAGE CASES

Landfill Name and Location	Date of Report/ Incident	Distance of Gas Migration*	Methane Detected Off-Site Above LEL	Explosion/ Fire Occurred**	Landfill Characteristics and Corrective Action*	Damages and Other Comments	Data Sources
Bakersfield Landfill Fresno, California	April 1984	N/A	Yes	Yes On-Site	• Control system installed after incident.	Fresno police bomb squad used the site to practice. A bomb was buried at the landfill and was detonated, causing an explosion. Explosive levels of methane were migrating off-site.	1
Operating Industeries Landfill Monterey Park, California	August 1983	---	Yes	No	• Class I landfill • LFG recovery system present • Control system existed prior to incident.	Vinyl chloride detection caused the SCAQMD to order 30-day shut down of the landfill. Landfill reopened, subject to closure in 6 months.	1
BKK Landfill West Covina, California	Aug-Oct 1984	250	Yes		• Class I landfill • Control system expanded after the incident	Twenty residences temporarily evacuated due to explosive methane levels in adjoining soils.	1,2
Wallingford Landfill Wallingford, Connecticut	January 1984	---	Yes	No	• LFG recovery system present.	Explosive levels of methane detected in dog pound. Dog pound temporarily closed. Ventilation system to be installed at the dog pound.	1,2
Shawnee County Landfill Topeka, Kansas	August 1983	---	Yes	No		Home abandoned due to high methane levels.	1
Monument Street Landfill Baltimore, Maryland	April 1983	---	[illegible]	No	• Solid waste with illegally dumped hazardous waste. • The soil type is clay with sand lenses interspersed. • The native clay serves as a liner.	Vent pipes were not maintained causing vents to become non-functional. Street light fire was believed to be related to methane migration. Ongoing lawsuit concerns presence of priority pollutants.	1,3,4
PJP Landfill Jersey City, New Jersey	1984	---	No	Yes On-Site	• Solid waste with illegally-dumped hazardous waste • It is an NPL site.	Fires in landfill have been a continuing problem for years, causing air pollution.	1

Symbols

N/A Not applicable
--- No information available
* Reported distance (in feet) of maximum migration, or distance to affected structure.
** Personal injuries sustained and/or death occurred.
* Landfills are municipal solid waste landfills (publicly or privately owned/operated) unless otherwise noted.

Sources

1. UPI or other news report
2. SCS Engineers
3. Contact with local officials
4. Princeton's Risk Assessment of the Monument Street Landfill
5. "Gas Control in Landfills: A Case Study" paper presented by Donald L. Feuerstein at the Fifth National Congress On Waste management Technology and Resource and Energy Recovery, Dallas Texas, December 7-9, 1976.

Attachment 4
(Source: SCS Engineers, 1985)

TABLE 1 : LANDFILL GAS MIGRATION DAMAGE CASES (Continued)

Landfill Name and Location	Date of Report/ Incident	Distance of Gas Migration*	Methane Detected Off-Site Above LEL	Explosion/ Fire Occurred**	Landfill Characteristics and Corrective Action*	Damages and Other Comments	Data Sources
Ocean County Landfill Manchester, New Jersey	December 1983	---	No	Yes On-Site	• Ventilation and alarm systems to be installed in the remaining maintenance garage.	Spark from landfill pump believed to have ignited methane gas, causing explosion and fire. One person injured with first, second degree and flash burns. Office building destroyed.	1
Wanaque, New Jersey	March 1984	---	Yes	No	• Control system proposed for school located on a closed landfill.	---	1
Babylon Landfill Commack, New Jersey	May 1984	50	Yes	Yes** On-Site	• Soils are sandy • No liner present • Control system installed after incident.	Explosion in scale-house killed one person and injured another. Methane migrated from the landfill to the scale-house on-site.	1,2
Hardy Road Landfill Akron, Ohio	1984	500- 1000	Yes	Yes** Off-Site	• No liner present • Control system installed after incident.	One house destroyed. Ten houses temporarily evacuated. People experienced minor injuries.	1,2
Landfill near Lake Township Canton, Ohio	September 1984	---	Yes	No	---	Two homes and a day care center temporarily evacuated.	1
Tyler, Texas	May 1982	N/A	No	No	• Control system existed prior to incident.	IDPS office building stands on a closed landfill. Methane has plagued it since it was built in the 1970's. When a ventilation system exhaust fan broke down, "significantly high" levels of methane were found in the building.	1
I-95 Landfill Lorton, Virginia	1984	100- 1000	Yes	Yes** Off-site	• No liner present • Soils range from clay to sandy clay to sand. • Control system installed after the incident.	One man was killed and another experienced burns on 50% of his body as a result of an explosion and limited fire.	1,2
Greentree Hills Landfill Madison, Wisconsin	November 1983	100- 150	Yes	Yes** Off-Site	• Soils are composed of clay, glacial fill, sand, weathered and fractured bedrock. • Liner may be present. • Control system expanded after the incident.	Explosion blew out one sidewall of a townhouse. Three nearby apartment buildings and several homes evacuated for 20-30 days. Two people seriously injured. Claims totaling 5.2 million filed against the city.	1,3

Attachment 4
(Cont.)

TABLE 1: LANDFILL GAS MIGRATION DAMAGE CASES (Continued)

Landfill Name and Location	Date of Report/ Incident	Distance of Gas Migration*	Methane Detected Off-Site Above LEL	Explosion/ Fire Occurred**	Landfill Characteristics and Corrective Action†	Damages and Other Comments	Data Sources
Mission Avenue Oceanside, California	1981	---	Yes	No	• No liner present • Control system installed after the incident	Schools surrounding the landfill were evacuated. Classes were not held for 4-5 months.	2
Unnamed Landfill Adams County, Colorado	1977	---	Yes	Yes** Off-Site	---	Explosion caused 2 fatalities and injured 7 others at a pipeline construction project adjacent to the landfill.	2
Reilly Construction Company Springfield, Illinois	1979	200	Yes	Yes** Off-Site	• No liner present. • Control system installed after the incident.	Methane migrated into construction company offices adjacent to the landfill. Limited fires occurred. No explosion. Building evacuated. Building use was restricted for 4 weeks.	2
Campground Landfill Louisville, Kentucky	1978	200	Yes	No	• No liner present. • Soils are sandy with clay and silt layers interspersed. • Control system installed after the incident.	No physical damages occurred. Buildings evacuated for short period of time.	2
Lees Lane Landfill Louisville, Kentucky	1974	1000	Yes	Yes** Off-Site	• No liner present. • Soils are clayey silt to gravelly sand. • Control system installed after the incident.	Small fires and explosions. Several houses evacuated and condemned. Benzene (29.5 ppm) and Vinyl chloride (17.9 122.6 ppm) detected off-site.	2
Allegany County Landfill Frostburg, Maryland	1978	200	Yes	Yes** Off-Site	• No liner present. • Soils are silt and clay. • Control system installed after the incident.	Limited fire in off-site equipment maintenance building. No explosion. Use of building restricted for 2 months. Building was highly ventilated until gas control system was installed.	2
Beantown Dump Rockville, Maryland	1980	N/A	No	Yes** Off-Site	• Old, inactive dump site. • Building constructed on inactive disposal site. • Control system installed after the incident.	Small explosion occurred in enclosed back room of auto body shop. A janitor was injured. Shop closed for 1 month until control system was installed.	2

Attachment 4
(Cont.)

TABLE 1: LANDFILL GAS MIGRATION DAMAGE CASES (Continued)

Landfill Name and Location	Date of Report/ Incident	Distance of Gas Migration*	Methane Detected Off-Site Above LEL	Explosion/ Fire Occurred**	Landfill Characteristics and Corrective Action†	Damages and Other Comments	Data Sources
Winston Salem, North Carolina	1969	100	Yes	Yes** Off-Site	• Codisposal • No liner present. • Control system installed after the incident.	Methane migrated into National Guard Armory. Explosion in the armory killed 3 guardsmen. Twelve were seriously injured and 25 other guardsmen experienced less serious injury. Seven of the injured have become partially or completely disabled.	2,5
Port Washington Landfill North Hempstead, New York	1981	2000	Yes	Yes** Off-Site	• Liner present • Soils are sandy with some clay and silt layers. • Control system installed after the incident.	Small explosions in furnace rooms of several homes. Minor damage occurred. Furnaces were replaced.	2
Smithtown Landfill Smithtown, New York	1984	200	Yes	Yes** Off-Site	• Liner is present. • Soils are sandy. • Control system existed prior to incident.	Explosion damaged room in transfer station building.	2
Anderson Township Landfill Cincinnati, Ohio	1983	300	Yes	Yes** Off-Site	• No liner present. • Control system installed after the incident.	Explosion destroyed residence across the street from the landfill. Minor injuries reported.	2
Warner Hill Landfill Cleveland, Ohio	1980	100	Yes	Yes** Off-Site	• No liner present. • Soils consist of silt and clay. • Control system installed after the incident.	Explosion killed a worker in foundry located adjacent to the landfill.	2
Kells Street Landfill Richmond, Virginia	1975	20	Yes	Yes Off-Site	• No liner present. • Soils are silty clay with some gravel. • Control system installed after the incident.	In 1975, an explosion occurred in a nearby apartment building. The city decided to buy and demolish it. Two schools located on the landfill were closed until a control system was installed.	2,3
	1982	N/A	No	Yes** On-Site	---	The 1982 incident was produced when kids trespassed onto the landfill site, entered a control system manhole, and lit a match, resulting in an explosion. The nature of the associated injuries has not been disclosed; the case is in litigation.	2,3

Attachment 4
(Cont.)

Attachment 5
(Source: Raymond Vail and Assoc., 1979)

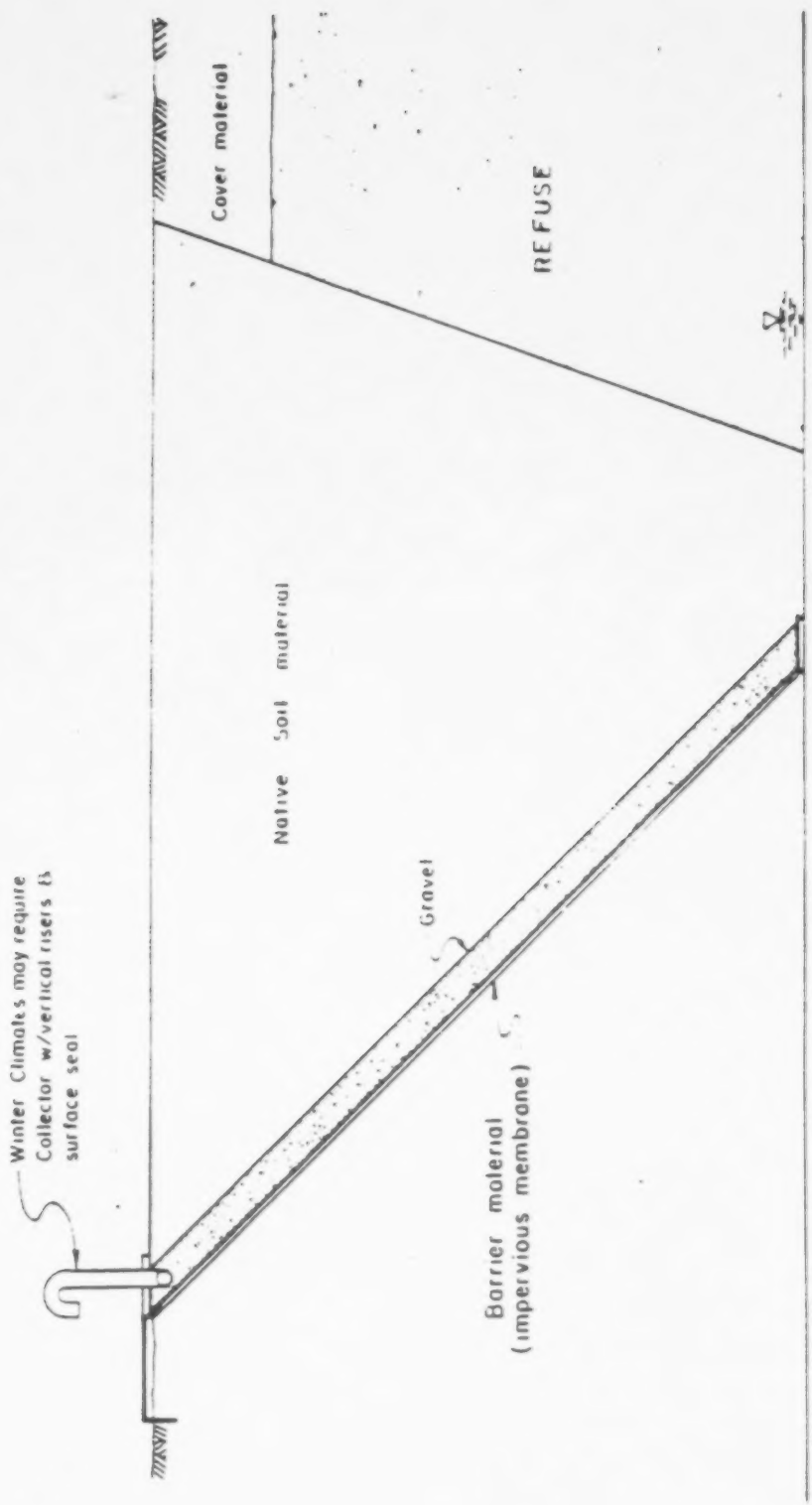

FIGURE 6 TRENCH BARRIER SYSTEM

Attachment 6
(Source: Raymond Vail and Assoc., 1979)

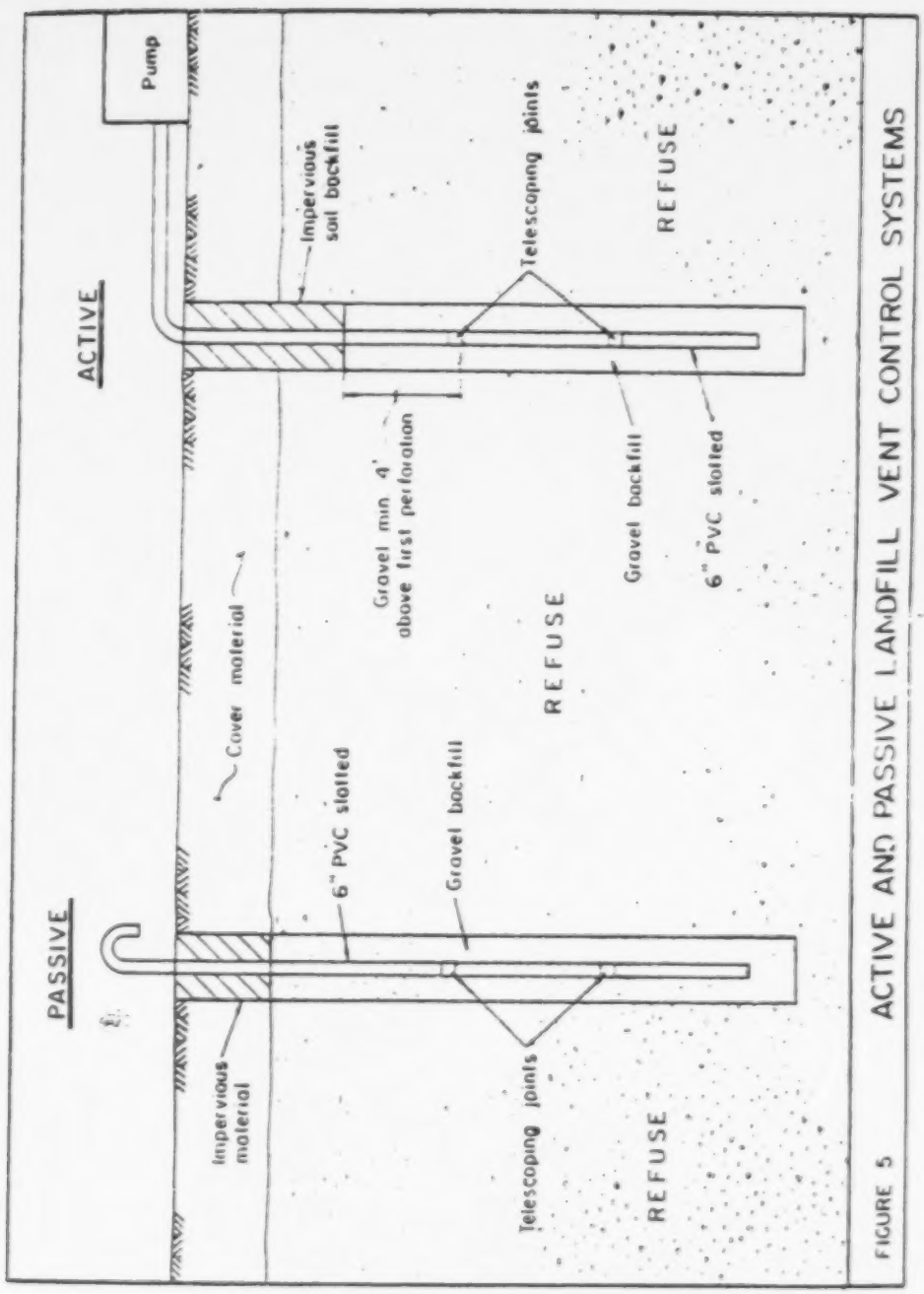

FIGURE 5 ACTIVE AND PASSIVE LANDFILL VENT CONTROL SYSTEMS

Attachment 7

LANDFILL GAS ISSUES AND OPTIONS

Presented to

U.S. Environmental Protection Agency
Office of Solid Waste
Land Disposal Branch

Presented by

SCS Engineers
11260 Roger Bacon Drive
Reston, Virginia 22090
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May 9, 1986

File No. 28286-19, LC 93

ISSUES RELATED TO SUBSURFACE GAS AT SUBTITLE D FACILITIES

May 8, 1986

ISSUE 1: CONSTITUENTS OF CONCERN

Option	Strengths	Weaknesses	Information Needs	Summary
A. Retain current criteria related to explosive gases (40 CFR 257.3-8 (a))	Readily understood and easily measured using relatively inexpensive, portable equipment. Addresses the most eminent subsurface gas hazards, i.e. explosion and fire. The presence (or absence) of methane is likely an indicator of the presence (or absence) of trace constituents.	Ignores potentially hazardous trace constituents frequently found in subsurface gas.	None	o No change in environmental protection o Easier implementation o Lower cost
B. Establish criteria for trace constituents as well as for explosive gases.	Would address trace constituents in subsurface gases that may have impacts other than explosion.	Reliable monitoring may be difficult and expensive.	Gases of concern would have to be identified and criteria established. Data on trace constituents and their impacts would have to be collected and interpreted. Definition of safe levels of trace constituents needed.	o More extensive environmental monitoring may lead to improved environmental protection. o More difficult implementation o Higher cost

Attachment 7 (Cont.)

ISSUE 2: STANDARDS FOR CONSTITUENTS OF CONCERN

Option	Strengths	Weaknesses	Information Needs	Summary
If Methane Only				
A. Retain current criteria (40 CFR 257.3-8 (a)) (LEL in soil at property boundary and 0.25 percent LEL in structures on the landfill).	Established criteria, easily understood, uniformly applicable and enforceable. No known criticism.	Allows no flexibility related to site location and risk potential. May unnecessarily increase costs at remote landfills.	None	o Good environmental protection o Easiest to implement o No cost increase over current regulations.
B. Establish new criteria.	May provide improved protection if lower levels are selected. If higher levels are selected, fewer control systems would be needed and costs reduced.	No data are available to support other criteria. Lengthy regulatory procedures required. No evidence that lower criteria will provide better protection. Increasing levels would increase risk.	Data relating methane concentrations to potential impacts.	o May be better environmental protection o More difficult to implement o Potentially higher costs
C. Establish risk-based, site-specific criteria.	Allows flexibility	Criteria would have to be developed to identify high-risk sites. Intepretation and enforcement may be difficult and uneven. Some sites posing a risk might be missed by the criteria. Does not provide a safe environment for future development near the site.	Information related to subsurface gas migration would have to be compiled and assessed to develop criteria.	o Most difficult to implement o May be highest cost o Good environmental protection

Attachment 7 (Cont.)

ISSUE 2 (continued)

Option	Strengths	Weaknesses	Information Needs	Summary
Other Constituents				
A. Establish specific criteria for trace constituents	Easily understood and uniformly applicable.	Allows no flexibility related to site location and risk potential. Requires monitoring at all sites which may not be necessary at remote landfills.	Data on trace constituents and their impacts would have to be collected and interpreted. Definition of safe levels of trace constituents needed.	o Good environmental protection o Easier to implement o Increased cost over current criteria (none)
B. Establish risk-specific criteria	Allows flexibility	Criteria would have to be developed to identify high-risk sites. These may be constituent dependent. Interpretation and enforcement may difficult and uneven. Some sites posing a risk might be missed by the criteria. Does not provide safe environment for future development near the site.	Information related to subsurface gas migration would have to be compiled and assessed to develop criteria. Information on subsurface fate and transport of trace constituents and their impacts may require R&D efforts. Definitions of safe levels of trace constituents needed.	o Good environmental protection o More difficult to implement o Lower cost than A

Attachment 7
(Cont.)

ISSUE 3: MONITORING

Option	Strengths	Weaknesses	Information Needs	Summary
A. No monitoring requirements placed on site operators. Compliance based on regulatory inspections.	Consistent with current criteria. Least impact and lowest cost for site operators.	No specific mechanism to routinely identify potential gas hazard. Hazard could develop between inspections. Inspection monitoring would be limited to shallow soil areas and accessible structures. Inspectors would have to be trained and equipped to conduct monitoring. Minimum protection. Decreases responsibility of site owner/operator to maintain safe conditions.	None	o Less environmental protection o No change from current practice o Less cost for operator. Higher cost for regulatory agency
B. Require site operators to periodically monitor all sites and report results.	Would provide routine information related to subsurface gas concentrations. May provide early warning of migration with resultant control being installed where required. Parallel requirements exist for ground-water monitoring at Subtitle C facilities.	Would place financial and operational burden on site operator. Would increase recordkeeping burden of regulatory personnel.	None	o Improved environmental protection o More difficult to implement o Higher cost
C. Require site operators to periodically monitor at select site and report results.	Similar to B, but only for these sites where monitoring is warranted. This is generally the practice followed by some of the more progressive states.	Similar to B. Determining which sites to require monitoring requires judgement.	Develop a criteria for sites requiring monitoring.	o Cost-effective environmental protection o More difficult to implement

Attachment 7
(Cont.)

ISSUE 4: TYPE OF MONITORING STANDARDS

Option	Strengths	Weaknesses	Information Needs	Summary
A. Designed-based standards should be required.	Monitoring system standards would be designed by LFG experts, yielding state-of-the-art equipment and procedures for gas monitoring. Proposed designs would be easy to evaluate against standard designs.	Numerous designs would have to be developed and disseminated to site operators and to regulatory personnel. Many site situations would not be covered by a standard design, thus variance procedures would have to be available with associated review and assessment procedures. Cost and time burden placed on regulatory agencies to develop designs.	Information on existing procedures and equipment would have to be gathered and standard designs developed.	o No change in environmental protection o Easier to implement o Same cost
B. Performance based standards would be required.	Allows tayloring the design to the site, a standard design may not fit the site. Minimum burden on regulatory agencies in specifying systems. Parallel to ground-water monitoring regulations for Subtitle C facilities. Relatively easy to develop specifications.	Each proposed monitoring system design would have to be evaluated for adequacy. Would require training of regulatory personnel and/or the use of LFG consultants.	Information about monitoring systems would have to be collected and technical guidance manuals and training provided.	o No change in environmental protection o More difficult to implement o Same cost
C. Performance-based standards with minimum design criteria.	Allows tayloring the design to the site, but provides a minimum design.	The minimum design may, in a few instances, be over-design.	Similar to A and B	o Improved environmental protection o Easier to implement o May be higher cost than B

Attachment 7
(Cont.)

LANDFILL GAS UPDATE, SUMMARIES OF TECHNICAL REPORTS

REPORT 1 Critical Review and Summary of Leachate and Gas Production from Landfill by F.G. Pohland and S.R. Harper, 1984.

REPORT 2 Volatile Organic Compounds in Gases from Landfill Simulators by W.G. Vogt and J.J. Walsh, 1984.

REPORT 3 Landfill Methane Recovery, Part I: Environmental Impacts by .E. Zimmerman and M.E. Goodkind, 1981.

REPORT 4 Landfill Methane Recovery, Part II: Gas Characterization by R.E. Zimmerman, N.W. Flynn, and V. Olivieri, 1982.

REPORT 5 Landfill Methane Recovery, Part III: Data Analysis and Instrumentation Needs by R.E. Zimmerman, G.R. Lytwynshyn, and N.W. Flynn, 1983.

REPORT 6 Demonstration of Landfill Gas Enhancement Techniques in Landfill Simulators by J.W. Stamm, W.G. Vogt, and J.J. Walsh.

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November 11, 1985
File No. 28286-19, LC 93

LANDFILL GAS UPDATE, SUMMARIES OF TECHNICAL REPORTS

As part of an assignment to provide the Land Disposal Branch with current information related to landfill gas, summaries of six recent reports on the topic were prepared. They are separately attached and are in the form of executive summaries that highlight the purpose and results of the technical investigations reported. Each summary is based only on the facts presented in the full-length articles. No attempt has been made to interrelate or compare one article with another or with other reports and articles. Some quantitative results are included; however, interested readers will have to obtain copies of the entire reports for full details.

REPORT 1 Critical Review and Summary of Leachate and Gas Production from Landfills by F.G. Pohland and S.R. Harper, 1984.

This report provides a review and summary of recent literature in the areas of leachate and gas production, containment, control, and treatment at landfills. The majority of this report addresses the subject of leachate. However, a thorough review of landfill gas is also presented. The authors deal with the subject of landfill gas by dividing it into three distinct areas: (1) factors affecting landfill gas production; (2) landfill gas production; and (3) collection and treatment of landfill gases.

The production of landfill gas is affected by the nature of disposed waste, moisture content, buffering capacity, availability of nutrients, temperature, and any site-specific gas extraction system. Each of these variables are natural extensions of environmental factors that affect anaerobic activity and specifically the family of methanogenic reactions. All of these parameters have been investigated at bench, pilot, or full scale basis. However, some conflicting results have been reported. It is generally accepted that the nature of waste (high organic content), increased moisture content (up to 60 percent), and buffer addition will result in higher methane yields and overall gas production rates.

Ultimate methane yields and gas production rates are important to the design of gas control systems and the economic feasibility of gas recovery projects. Gas yield projections may be made with stoichiometric models or empirical gas yield models. Most stoichiometric models estimate gas generation based on assumptions of the chemical composition of municipal solid waste. Most of these models also incorporate the Buswell equation for methanogenesis. Stoichiometric models are prone to error and when compared to field data predict production rates on the order of 50 to 90 percent of that data.

Empirical gas models are generally based on experimental data collected during field investigations and landfill simulator (lysimeter) studies. While this application of experimental data often serves as the best indicator of actual gas yields, these empirical models have some inherent shortcomings. Problems that were identified in the general design of empirical models include:

- The smaller scale employed in laboratory studies.
- The shorter length of time data is collected in laboratory studies.
- Leaking of the lysimeters used in laboratory studies.
- Hydraulic short-circuiting within the vessel (lysimeter).

In spite of these problems, landfill simulation and actual field data tend to correlate relatively well.

Gas composition is an important aspect of ultimate gas yields and production rates. Landfill gases are typically 40 to 60 percent methane with the remaining portion consisting primarily of carbon dioxide and 1 to 2 percent of other miscellaneous organic and inorganic vapors. The composition of the miscellaneous fraction has become an important issue in recent years. Initial studies have identified 69 individual organic compounds within this small fraction of gas. In some cases, concentrations were in excess of several OSHA/NIOSH exposure limits. These exposure limits included the Permissible Exposure Level (PEL), Time Weighted Average (TWA) and Immediately Dangerous to Life and Health (IDLH).

The design for the collection and treatment of landfill gas depends upon the intended use of the gas. Gases may be withdrawn simply to prevent migration or may be treated and used as a fuel. Active gas collection systems generally consist of perforated pipe extraction wells connected to a single pipeline called a header. The header line is then connected to one or more blowers (or compressors) to provide a source of vacuum to the header and extraction wells. After the system is under a vacuum, migrating gas will tend to follow the pressure gradiant through the perforated pipe as opposed to continued migration through the soil. After the extracted gas has been collected, it is eliminated by using a flaring system or in some cases (low methane content) by release to the atmosphere. Other system components include metering and monitoring equipment to document and record gas composition and flow rate.

If landfill gas is intended for use as a fuel, it must be treated, because most raw landfill gas has a low heating value due to the dilution of methane with carbon dioxide. Treatment technologies are available for producing landfill gas at either medium-Btu (500 to 600 Btu/scf) or pipeline quality (1,000+ Btu/scf). Medium-Btu gas is produced by removing water vapor and possibly hydrogen sulfide. The condensed water vapor is either treated or returned to the landfill.

Pipeline quality gas has a high degree of purity and generally requires a water vapor content less than 0.0001 kg/cu m, and carbon dioxide removal in sufficient quantities to yield a gas rated at 1,000 Btu/scf or more. Treatment unit operations include physical/chemical adsorption, membrane separation, and refrigerated drying. The economic evaluation of various treatment schemes have shown probable payback periods between 3 and 30 years based on an energy value equivalent to revenue of $1.9/mmKJ (million kilojoules) (1979 dollars).

REPORT 2 Volatile Organic Compounds in Gases from Landfill Simulators by W.G. Vogt and J.J. Walsh, 1984.

Field investigations at various landfill sites have detected a variety of vapor-phase organic compounds (VOC's) in landfill gas. Though potential exposure of these compounds to the public may be minimal, the presence of VOC's has raised health and safety questions in the environmental community. The Gas Research Institute funded this project to characterize VOC levels under controlled conditions using landfill waste of known physical and chemical composition. The project objectives were:

- Determine the presence of trace VOC's in the gases generated from several landfill simulators.
- Determine the release versus retention of spiked volatile organic compounds from sludge-codisposal landfill simulators.
- Determine differences between VOC emissions from municipal solid waste (MSW) only and sludge-codisposal landfill simulators.
- Compare results from pilot-scale simulated landfills to previous results from selected full-scale landfills.

Landfill simulation is often performed on a laboratory scale using test cells (or chambers) called lysimeters. Lysimeters are normally loaded with municipal solid waste and/or sludge. This scenario was followed in this project using various loading ratios of sludge to MSW and spikes of organic priority pollutants. Six lysimeters were established for this project. Two units acted as codisposal landfills, while a second set of two lysimeters represented codisposal landfills spiked with a mixture of priority pollutant compounds. The final set of two lysimeters contained only municipal solid waste and served as a control. Monthly gas samples were collected by pumping a known volume of gas from the test cells through an adsorbent resin column and were analyzed for organic compounds.

During the 12-month project period, 56 organic compounds were detected. The range of concentrations of hexane, benzene, toluene, and nonane was 1.3 to 8.8 volume parts per million (Vppm), while all other compound concentrations remained consistently below 1.0 Vppm. VOC concentrations emitted from the sludge codisposal lysimeters were greater than VOC levels from municipal solid waste only. Of the organic compounds introduced as a priority pollutant spike, only benzene and toluene were detected at elevated concentrations in the test cell gases. Generally, these experimental VOC concentrations were familiar to field VOC results collected from full-scale landfills. The data from the laboratory lysimeter tests always fell within one order of magnitude for the mean and maximum values. Results from this study suggest that laboratory-scale landfill simulators can be used as an effective tool in predicting VOC emissions and concentrations from full-scale landfills.

REPORT 3 Landfill Methane Recovery, Part I: Environmental Impacts by R.E. Zimmerman and M.E. Goodkind, 1981.

This report addresses the environmental impacts of the recovery of landfill gas (LFG). Regulatory, licensing, environmental, and safety issues are also presented for consideration. This project was cofunded by the Gas Research Institute (GRI) and the U.S. Department of Energy (DOE). The objectives of this report were:

- Review the state-of-the-art of landfill gas recovery.
- Identify the impacts of landfill gas recovery and evaluate their importance.
- Identify the significant laws and regulations (existing and proposed) applicable to the LFG recovery industry.
- Identify and discuss environmental and safety issues of landfill gas recovery.

A typical recovery system consists of a series of horizontal or vertical wells, connection piping, blowers, and gas processing operations. The design and placement of collection wells involves an estimate of the most productive configuration of the well field based on the "sphere of well" influence for individual wells and the area of the landfill to be developed. A "sphere of well influence" is defined as that landfill volume from which LFG may be extracted. Typical well depths range from 30 to 100 ft. Collection piping from wells may be placed above or below the surface.

Treatment processes remove water vapor, carbon dioxide, nitrogen, acids, and odorous contaminants. Water may be removed by lowering the gas temperature, by glycol treatment, or by use of adsorption systems. A number of techniques are available for carbon dioxide removal, including absorption into a liquid, adsorption onto a solid, membrane separation, cryogenic separation, or chemical conversion to other compounds. The treatment of landfill gas to pipeline quality requires capital-intensive processing equipment. Multiple-step treatment systems are usually necessary for removal of higher molecular weight hydrocarbons, trace gases, and carbon dioxide. Several case studies on the recovery and control of landfill gas are outlined and discussed.

The most significant environmental regulations for landfill gas control and recovery projects are:

- Resource Conservation and Recovery Act (RCRA)
- Toxic Substances Control Act
- Clean Air Act

S1

- Clean Water Act
- National Environmental Policy Act

These laws will result in:

- Increased involvement of state agencies in reviewing existing and planned facilities.
- Stricter limitations on site locations.
- Increased requirements for monitoring methane.
- Increased construction and operating costs in order to achieve greater environmental protection and collect monitoring data.

The general conclusions of the study were that incentives for LFG recovery development will depend on costs of other energy sources, the desire for diversification of energy sources, and costs related to environmental controls. Research to reduce technological uncertainties that may impede the full utilization of this resource potential was recommended.

REPORT 4 Landfill Methane Recovery, Part II: Gas Characterization by R.E. Zimmerman, M.W. Flynn, R. Wingender, and V. Olivieri, 1982.

Methane produced during anaerobic decomposition in sanitary landfills is an alternative fuel that may be removed from existing landfills, processed, and utilized. Estimates place the quantity of gas ultimately available at 1 percent of the nation's energy needs, or approximately 5 percent of the nation's current natural gas consumption. One of the major impediments to commercialization of this technology has been the lack of specific knowledge of the environmental and safety aspects (including the benefits) of landfill methane recovery (LMR) operations.

One benefit of LMR is that processing and removal of gas from a landfill has the net effect of improving local air quality by reducing the gaseous emissions, especially hydrocarbons, from the landfill site. The objective of the GRI/DOE Landfill Methane Recovery Research Program is an effort to document the net effect of LMR on the environment. The objectives of this study were to:

- Develop and evaluate standardized landfill gas sampling procedures and analytical techniques.
- Develop a data base on the volatile organic compounds and volatile mercury in landfill gas.
- Evaluate the feasibility of implementing standardized sampling and analysis protocols at different laboratories.
- Determine the presence of human pathogenic viruses or bacteria in the gas.
- Develop further research recommendations.

The analysis of samples for VOC's and volatile mercury was performed at two analytical laboratories: Argonne National Laboratory, Argonne, IL; and Science Applications, Inc., LaJolla, CA. A third laboratory, Johns Hopkins University, evaluated selected samples for the presence of human pathogenic, viral, and bacterial organisms.

Repetitive sampling and analysis for nine sites provided the opportunity to evaluate agreement (or differences) within a laboratory and between the two analytical laboratories. Sampling and analytical protocols used by both laboratories were identical, however, the analytical hardware and interpretive computer hardware and software were different. The most significant differences in analytical results between the two laboratories were observed during the early portions of the program, and are attributed in large part to the use of a procedure new to one laboratory, differing intralaboratory standards, and possible systematic variations in sampling and analytical procedures. Later in the program these differences decreased, and the data indicated good agreement between laboratories. The reported level of

confidence that can be applied to the quantitative analyses is within an order of magnitude. The qualitative analytical results obtained from the two laboratories indicate consistent agreement in identification of volatile compounds including environmentally significant compounds and other (non-significant) compounds.

The quantitative analytical results produced by each laboratory indicate that there is a range of concentrations (up to one order of magnitude) for environmentally significant compounds at different landfill sites and from different rounds of sampling at the same site.

The general trend of the VOC concentration data shows a reduction in trace VOC's from inlet gas to product gas to surface gas. The removal efficiency ranges from over 70 percent for benzene and methyl benzene to below 30 percent for dichloromethane and nonane. Variations from this general trend may be due to constituent concentration due to the removal of carbon dioxide (i.e., reducing the volume of the gas), or by reactions during the processing of the gas, or other unknown factors. The data also demonstrate a general trend of decreasing VOC concentrations corresponding to an increased level of gas processing. VOC removal often approaches a one order of magnitude difference in concentration when highly processed landfill gas was compared to moderately processed landfill gas.

The study shows that mercury is not present in raw or treated gas in environmentally significant amounts at the tested sites. Mercury concentrations observed in this study are very low, especially compared to the "Threshold Limit Value" of 0.1 mg per liter (11.1 Vppm) for inorganic mercury. The average values for mercury concentrations range from 134 x 10^{-6} Vppm to 370 x 10^{-6} Vppm for gas sampled at the surface of the landfill. No indicator or pathogenic bacteria or human pathogenic viruses were recovered in any of the samples of inlet and processed landfill gas.

The results of the flux rate testing were inconclusive for defining the rate of gas flux through the landfill surface. Surface flux rates vary from 0 to 15.6 standard cubic feet per square feet per day (scf/sq ft/day). Excluding two high flux rates (14.8 and 15.6 scf/sq ft/day), the range of observed flux rate data changed to 0 to 0.28 scf/sq ft/day. This range agrees with other data reported by Cagliostro and Gargano (1979) and Kunz and Lu (1980).

The study presents a number of research recommendations, including:

- Correct and insert available project data into the VOC data base and perform a statistical analysis of the newly expanded data base.
- Identify equipment and instrumentation needs for the LMR industry and for GRI member companies interested in LMR.

- Review surface flux research in other industries, including a summary of the theoretical basis of surface flux modeling, and develop surface flux measuring methodologies and instrumentation, if needed, which will allow for collection of more accurate surface flux information.

Report 5 Landfill Methane Recovery, Part III: Data Analysis and Instrumentation Needs by R.E. Zimmerman, G.R. Lytwynshyn, and N.W. Flynn.

This report is the final part in a three-part study of landfill methane recovery (LMR). Based on the two previous Gas Research Institute (GRI) studies, the thrust of this project was to statistically analyze and validate the volatile organic compound (VOC) data base assembled under the project entitled "LMR Part II: Gas Characterization" (1982). A second task of this project was to document the instrumentation needs of LMR, the commercial availability of equipment, and the need to develop equipment. These tasks were intended to accomplish the following objectives:

- Expand the level of statistical analysis undertaken in LMR Part II.
- Determine the current instrumentation needs of the landfill gas processing industry.
- Determine currently available equipment that satisfies the instrumentation needs of the industry.
- Identify instrumentation development needs.

The first step of this project was to provide a more detailed statistical analysis of the VOC data base collected in LMR Part II, Gas Characterization (1982). This was accomplished using a computer software package called Statistical Analysis System (SAS). Prior to evaluation, the entire VOC data base was reviewed for accuracy and completeness against the original reported laboratory results. This review resulted in less than 10 revisions in the 10,000 data entries. Using the corrected data base and statistical package, various trends and correlations were investigated for 20 individual compounds in three VOC categories. These categories were chlorinated compounds, alkanes, and aromatics. From these analyses, the following conclusions were made:

- Laboratory procedures should be revised to include control of moisture in both field sampling and laboratory testing and to reduce sample turn around time.
- Proper use of laboratory standards is critical to the achievement of accurate results.
- A removal of total VOC's (85 percent to 92 percent efficiency for chlorinated compounds) occurs in landfill gas as it undergoes high-Btu processing.
- Data anomalies identified a need for a comprehensive systems analysis of LMR processing plants including a complete mass balance of the methane fraction and the trace component fraction of landfill gas.

- There was no correlation between the trace VOC content of the landfill gas and landfill location, age, or depth. Variations may occur with a change in waste materials.

The second portion of this study examined the instrumentation needs and practices of the LMR industry and identified potential sources of monitoring equipment. The first step was to conduct personal and telephone interviews with LMR personnel to establish an overview of instrumentation usage anc the perceived needs of the industry. After assembling a list of analytical needs, a market survey of instrumentation manufacturers was conducted to determine the equipment currently available for LMR applications. Finally, the results of these two steps were cross-referenced to evaluate how well current technology addresses the needs of the LMR industry.

The survey of instrumentation needs indentified four general areas where the LMR industry required instrumentation. A summary of recommendations is:

- Evaluation of the faster-response miniature gas chromatographs for VOC detection in landfill gas streams.

- Instrumentation data should be centrally collected and made available to utilities and others in the gas industry.

- Initiation of development programs to evaluate specific needs and equipment applications.

A by-product of the instrument survey was a useful glossary of instrumentation terms that may prove useful to the non-instrumentation oriented professional.

REPORT 6 Demonstration of Landfill Gas Enhancement Techniques in Landfill Simulators by J.W. Stamm, W.G. Vogt, and J.J. Walsh, 1985.

In March 1979, the Department of Energy (DOE) announced its intention to fund projects in the areas of research, development, and demonstration of landfill gas utilization. This action came in pursuit of its objective to develop waste-to-energy processes in the biological area. The thrust of this effort was to investigate optimal methane recovery through improved design, construction, and operational techniques in both the generation and collection of landfill gas from existing or new full-scale landfills. In May 1979, SCS Engineers (SCS) was awarded one of five projects dealing with landfill gas enhancement techniques. In 1982, the Gas Research Institute (GRI) granted a continuation of this study.

The primary objective of this program was to evaluate the effectiveness of the following landfill gas enhancement techniques:

- Accelerated moisture through-put.
- Elevated moisture content.
- Leachate recirculation.
- Buffer addition/pH control.
- Nutrient addition.
- Sewage sludge addition.
- Elevated operating temperature.

The effectiveness of these enhancement techniques was to be judged on the following criteria:

- Landfill gas and methane production (both on a total volume and per weight of solid refuse basis).
- Rate of landfill gas and methane production.
- Quality of landfill gas (percent methane, carbon dioxide, nitrogen, and oxygen).
- Environmental concerns.

The research project involved the use of laboratory scale test cells (lysimeters) that simulated miniature landfills. The design of the lysimeter led to a durable, gas-tight container of sufficient scale to promote the decomposition processes that occur in an actual landfill. The cells were rolled steel, double-welded at the seams, with two interior coatings of rust-proof, high-bond epoxy sealer. Further features included a gas collection

system, infiltration line, leachate drain, and an opening for temperature probes.

Various operations and monitoring activities were performed on a continuous basis throughout each experiment. Gas volumes were measured on a daily (or as needed) basis for each of the 16 test cells. In addition, leachate was drained from each cell monthly and the volume recorded. Each test cell then received fresh water applications as infiltration and/or as recycled leachate. Representative leachate samples were obtained from each cell for standard chemical analyses including detection of six trace metals.

The final report covers the project's entire 5 years of operation from February 1980 through January 1985. Both qualitative and quantitative data for landfill gas and leachate are presented and discussed. This data encompasses gas volumes, gas composition, and 17 leachate parameters including pH, alkalinity, chemical oxygen demand, and six trace metals. The following is a summary of the results and conclusions from this study. It is important to note that the test cells were numbered 20 through 35 due to the presence of other lysimeters used in different projects.

Test Cell 20 was designated as a control cell and because of its low rate of infiltration, should best represent typical landfill conditions. The final cumulative gas generation rate for Cell 20 was 2.3 l/kg/yr. Iteractive methane production from this cell ranged from 0.05 to 0.6 l/kg/yr with a cumulative methane generation rate of 0.22 l/kg/yr.

The first set of enhancement techniques included cells in which a high moisture level was maintained by accelerated water "through-put". This included Cells 21, 22, and 23. Test Cells 22 and 23 both received high rates of infiltration and responded with methane production rates 86 to 880 percent higher than control cell levels. Test Cell 21, in which moisture content was elevated during the final two years of operation, yielded methane production 160 percent higher than the control cell. This loading parameter also caused a marked increase in the rate of typical decomposition processes.

The practice of leachate recycle in conjunction with various loadings of buffer and nutrient additives encompassed the second set of enhancement techniques. This group of cells included Test Cells 24, 26, 28, 30, and 31. As a group, the leachate recycle cells generated less methane than the control cell. These cells showed a methane production rate 3 to 65 percent lower than the control cell. Neither buffer nor nutrient addition seemed to reverse the negative effects of leachate recycle.

The third group of lysimeters received additions of anaerobically digested sludge. This group included Test Cells 25, 27 and 29. The effects of this enhancement technique resulted in dramatic increases in cumulative methane production rates often 50 times greater than the control test cell. Thus slude addition provided the greatest increase in methane generation and the greatest increase in methane generation anaerobic decomposition in these cells. In

general, buffer and nutrient addition when applied to sludge-addition test cells, did not have a pronounced effect on methane production.

The final enhancement technique utilized the addition of either buffer or nutrient compounds to Test Cells 32 and 33 (buffer addition) and Test Cells 34 and 35 (nutrient addition). The buffer addition cells had cumulative methane production rates ranging from 25 to 36 times greater than the control cell. The nutrient addition cells demonstrated methane generation 1 to 20 times higher than the control. The findings and conclusions presented are based on results collected under tightly controlled laboratory conditions. Gas production or methane generation data from lysimeters cannot be directly extrapolated to "real-world" landfill sites. There is one important difference between buffer and nutrient addition. The addition of nutrients caused an almost immediate increase in methane production, while the use of a buffer required a significant time lag before methane production increased. In general, additions of either buffers or nutrients caused methane generation in increase.

In conclusion, the following observations were made:

- Sludge addition provided the greatest increase in methane production regardless of other loading or operational variables. The addition of sludge caused an immediate response in total gas and methane production.

- The addition of either buffer or nutrient compounds also produced considerable increases in methane generation. The addition of nutrients caused an immediate response in total gas and methane production. The use of buffer compounds resulted in a definitie delay before total gas and methane production increased.

- Increased moisture content resulted in marked increases and shorter response times in methane production, as much as the increase resulting from but not sludge or chemical nutrient addition. Accelerated moisture through-put required a definite time delay, before increasing total gas and methane production increased.

- Leachate recirculation failed to increase methane yields. Using gas generation and water quality as benchmarks, leachate recycle did accelerate typical decomposition processes.

- The techniques of leachate recycle, accelerated moisture through-put, and elevated moisture content could cause leachate treatment problems due to increased concentration of contaminant.

- The addition of chemical additives did not appear to cause signficant effects on leachate quality.

- Based on this project's definition of enhancement technique, sludge addition is clearly the superior landfill gas enhancement technique.

TABLE 4-7. SAFETY REQUIREMENTS

State	Unauthorized open burning prohibited	Fire			Access						Adverse weather disposal
		Adequate measures	Control procedures	Other emergency requirements	All-weather roads	Prevent uncontrolled access	Barriers required	Identification signs	Attendant required	Maintain roads	
Alabama	x	x			x	x	x		x		x
Alaska	x					x				x	
Alaska[c]	x					x				x	
Arizona	x	x			x						
Arkansas			x		x	x	x	x	x	x	x
California	x	x	x	x	x	x	x	x	x	x	
Colorado	x					x	x				
Connecticut	x	x	x		x			x	x	x	
Delaware		x			x	x	x		x		
Dist. of Col.[d]											
Florida	x	x			x	x	x	x	x		x
Georgia	x	x			x	x			x		
Hawaii		x			x	x					
Idaho	x	x		x	x	x	x	x	x		
Illinois	x	x		x		x	x	x	x	x	
Indiana	x	x			x	x		x	x	x	
Iowa	x	x			x	x	x	x	x		x
Kansas		x		x	x	x	x	x			
Kentucky	x	x	x	x	x	x		x	x		
Louisiana	x	x			x	x	x				
Maine	x		x	x	x	x	x	x	x		
Maryland	x	x	x		x	x			x		x
Maryland[c]	x	x	x		x	x			x		x
Massachusetts	x	x	x	x	x	x	x	x	x	x	x
Massachusetts[c]	x	x	x	x	x	x	x	x	x	x	x
Michigan	x				x	x	x		x	x	
Minnesota	x				x	x	x	x			
Mississippi	x			x	x	x		x	x		
Missouri	x		x	x							
Montana	x				x	x	x	x	x		
Nebraska	x	x				x	x	x	x	x	
Nevada	x	x			x	x		x	x	x	x
New Hampshire	x	x	x		x	x	x	x	x		

(continued)

Attachment 9
(Source: PEI, 1986)

TABLE 4-7 (continued)

State	Unauthorized open burning prohibited	Fire			Access						Adverse weather disposal
		Adequate measures	Control procedures	Other emergency requirements	All-weather roads	Prevent uncontrolled access	Barriers required	Identification signs	Attendant required	Maintain roads	
New Jersey		[a]	x				x	x	x		
New Mexico	x	x									
New York	x	x			x	x		x		x	
North Carolina	x	x		x	x	x	x	x	x		
North Dakota	x	x		x	x	x	x	x	x		
Ohio	x	x	x		x	x			x		x
Oklahoma	x	x			x	x	x	x			
Oregon	x	x		x	x	x	x	x			
Pennsylvania	x	x		x	x	x	x	x	x	x	x
Rhode Island	x	x		x		x	x	x	x		
South Carolina	x				x	x	x	x	x		x
South Dakota	x	x		x	x	x	x	x			
Tennessee	x	x			x	x	x	x	x		x
Texas	x	x	x	x	x	x	x	x	x		
Utah	x	x		x					x		
Vermont	x				x[b]		x		x		x[b]
Virginia	x	x		x	x						
Washington	x	x		x	x	x	x	x	x		
West Virginia	x	x				x					
Wisconsin	x	x		x	x	x	x	x	x		
Wyoming	x	x			x	x	x	x			x
Am. Samoa										x	
Guam	x		x		x	x					
N. Mariana Is.[c]	x	x	x		x	x	x				
Puerto Rico	x										
Virgin Is.											

[a] Information not received.

[b] In guidelines.

[c] Proposed regulations.

Attachment 9
(Cont.)

Attachment 10
(Source: EPA, 530-SW-86-022B, 1986)

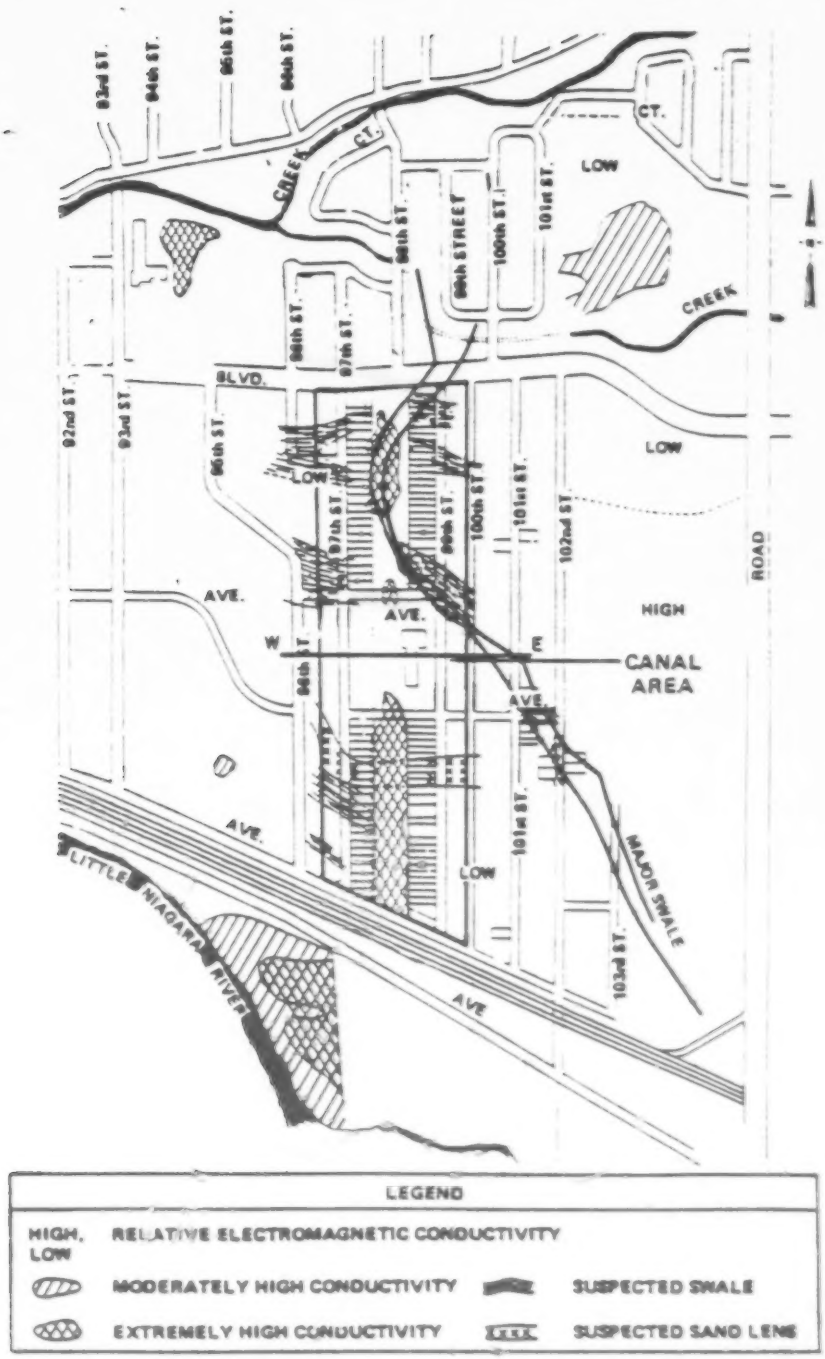
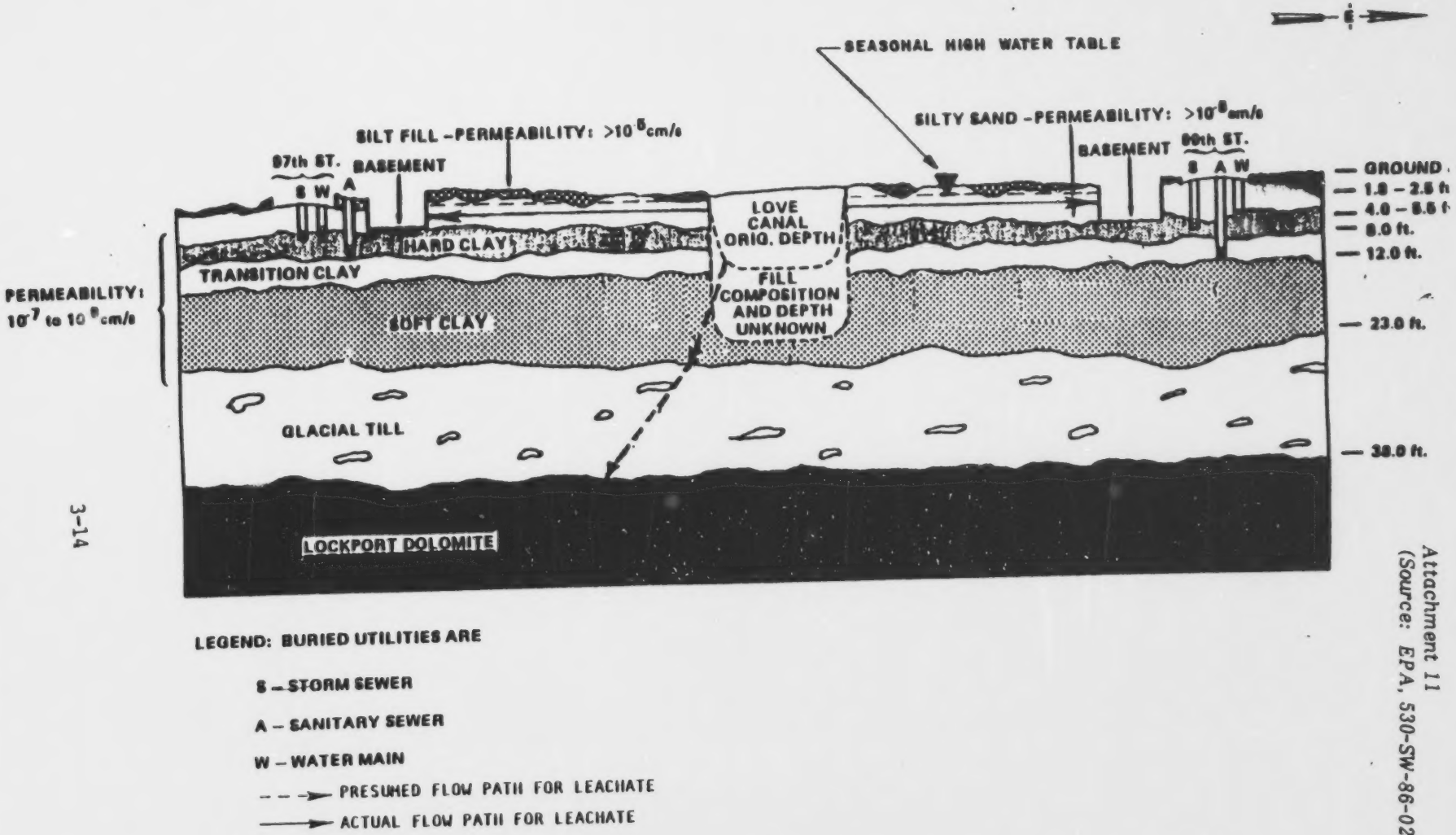


FIGURE 3.1-1 Site map showing location of E-W transect and major surficial features at Love Canal. (Adapted from EPA 600/4-82-030a).



Attachment 11
(Source: EPA, 530-SW-86-022B, 1986)

FIGURE 3.1-2 West-East cross section of Love Canal (Looking North from a position located South of Wheatfield Avenue). Adapted from EPA 600/[illegible]82-030a).

Table 4-21. PRELIMINARY DATA ON CONCENTRATIONS OF ORGANIC CONSTITUENTS IN LEACHATE FROM MUNICIPAL SOLID WASTE LANDFILLS

Compound	Number of Sites at Which Constituent was Detected	Concentration Range (ppb)	Median Concentration (ppb)	Promulgated Standards or Criteria (ppb)
Acetone	12	8 - 11,000	430	4,000[b]
Acrolein	1	270 - 270	270	21[d]
Benzene	18	4 - 1,080	37	5[a]
Bromomethane	1	170-170	170	10[b]
Butanol	1	1,000-1,000	1,000	
1-Butanol	2	320-360	340	
Butylbenzylphenol	2	21 - 150	125	
Carbon tetrachloride	2	6-398	202	5[a]
Chlorobenzene	8	1 - 685	7	1,000[b]
Chloroethane	7	11 - 860	28	
Bis-(2-Chloroethoxy) methane	2	18 - 25	22	
2-Chloroethylvinyl ether	1	2 - 1,100	551	
Chloroform	8	27-31	29	5.9[c]
Chloromethane	3	170 - 400	175	
Bis-(Chloromethyl) ether	1	250 - 250	250	0.0037[c]
2-Chloronaphthalene	1	46 - 46	46	
p-Cresol	5	45-5,100	2,305	2,000[b]
2,4-D	5	7 - 220	130	400[b]
4,4-DDT	5	0.042 - 0.22	0.105	0.1[c]
Dibromomethane	1	5-5	5	
1,2-Dichlorobenzene	5	3-22	12	3,000[b]
1,4-Dichlorobenzene	8	1 - 52	7	75[a]
Dichlorodifluoromethane	5	10-450	274	7,000[b]
1,1-Dichloroethane	20	4 - 44,000	165	0.58[c]
1,2-Dichloroethane	6	1 - 11,000	10	5[a]
Cis-1,2-Dichloroethylene	2	190-470	330	
Trans-1,2-Dichloroethylene	21	2-4,800	92	
1,2-Dichloropropane	9	0.03-500	9	5,700[d]
1,3-Dichloropropene	2	18 - 30	124	0.19[c]
Diethyl Phthalate	12	3 - 330	83	460,000[b]
2,4-Dimethylphenol	2	10 - 28	19	2,120[d]
Dimethyl phthalate	2	30 - 55	43	313,000[d]
Di-n-Butyl phthalate	5	12 - 150	49	4000
Endrin	3	0.04-50	0.25	0.2[a]
Ethanol	1	2,300-2,300	2,300	
Ethyl acetate	2	42-130	86	

Table 4-21. (continued)

Compound	Number of Sites at Which Constituent was Detected	Concentration Range (ppb)	Median Concentration (ppb)	Promulgated Standards or Criteria (ppb)
Ethylbenzene	25	6 - 4,900	58.5	4,000[b]
Bis-(2-ethylhexyl) phthalate	8	16-750	80	70[b]
2-Hexanone	6	6 - 690	88	
Isophorone	6	4 - 16,000	76	5,200[d]
Lindane	1	0.017-0.023	0.020	4[a]
Methyl ethyl ketone	13	110-27,000	1,550	2,000[b]
Methyl isobutyl ketone	7	10 - 710	270	2,000[b]
Methylene chloride	32	2-220,000	440	4.8[c]
Naphthalene	13	2 - 202	12	620[d]
Nitrobenzene	3	4 - 120	40	20[b]
4-Nitrophenol	1	17 - 17	17	150[d]
Pentachlorophenol	2	3 - 470	45	1,000[b]
Phenol	21	7 - 28,800	378	1,000[b]
1-Propanol	1	11,000-11,000	11,000	
2-Propanol	4	94-26,000	8,450	
1,1,2,2-Tetrachloroethane	1	210 - 210	210	1.7[c*]
Tetrachloroethylene	11	2 - 620	55	6.7[c*]
Tetrahydrofuran	6	18-1,300	260	
Toluene	32	6-18,000	413	10,000[b]
Toxaphene	1	1-1	1	5[a]
1,1,1-Trichloroethane	13	1-13,000	86	200[a]
1,1,2-Trichloroethane	3	30 - 630	426	6.3[c*]
Trichloroethylene	17	1-1,300	43	5[a]
Trichlorofluoromethane	9	4-150	34	,000[b]
1,2,3-Trichloropropane	1	230-230	230	7,000[b]
Vinyl chloride	6	8 - 61	40	2[a]
m-Xylene	7	10-171	68	
Xylenes	6	32 - 310	71	70,000[b]

SOURCE: Reference 5, Reference 7, Reference 8, Reference 9, Reference 10, Reference 11, Reference 12, Reference 13, Reference 14, Reference 15, Reference 16, Reference 17, Reference 18

a Maximum contaminant level, EPA's drinking water standard.
b Concentration based on U.S. EPA verified reference dose for systematic toxicants and the assumption of a 70Kg adult consuming 2 liters of water per day.
c Constituent is considered a carcinogen by the oral route. Concentration is based on a unit risk of 10^{-6} except where noted.
d EPA water quality criteria.
* Concentration based on a 10^{-5} risk level (this is a class C carcinogen).

NOTE: The EPA is presently evaluating these data in a separate report titled Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics. This report is being prepared by NUS Corp. under contract 68-01-7310 as a background document for the work assignment "Criteria for Municipal Solid Waste Landfills."

Table 4-22. RANGE OF VARIOUS INORGANIC CONSTITUENT AND PARAMETER CONCENTRATIONS IN LEACHATE FROM MUNICIPAL SOLID WASTE LANDFILLS

Compound	Number of Sites at Which Constituents was Detected	Concentration Range (ppm)	Median Concentration (ppm)	Promulgated Standards or Criteria (ppm)
Alkalinity	29	470-57,850	2,650	
Aluminum	7	0.01 - 5.8	2.4	
Ammonia	44	0.39-1,200	209	
Antimony	9	0.0015-47	0.066	0.01[b]
Arsenic	36	0.0002-0.982	0.0135	0.05[a]
Barium	36	0.11 - 5	0.58	1.0[a]
Beryllium	6	0.001 - 0.01	0.005	0.2[b]
Biological Oxygen Demand	33	7-29,200	2,310	
Boron	8	0.63-12	4	
Cadmium	31	0.007-0.15	0.0135	0.01[a]
Calcium	19	96-2,100	320	
Chemical Oxygen Demand	52	42-50,450	2,800	
Chloride	52	31 - 5,475	594	
Chromium (Total)	43	0.0005-1.9	0.06	0.05[a]
Cobalt	2	0.04-0.13	0.08	
Conductivity (umhos/cm)	55	300 - 36,000	5,600	
Copper	33	0.003-2.8	0.054	0.012[b]
Cyanide	13	0.004 - 0.02	0.03	0.7[b]
Eh (millivolts)	6	383-804	481	
Fluoride	18	0.11-302	0.39	
Hardness	26	0.8-9,380	1,665	
Iron	55	0.22-2,280	95	1,000[c]
Lead	45	0.005-1.6	0.063	0.05[a]
Magnesium	18	74 - 927	136	
Manganese	43	0.03 - 79	3.7	0.05[c]
Mercury	16	0.0001 - 0.01	0.0006	0.002[a]
Nickel	37	0.02 - 2.2	0.17	0.5[b]

Table 4-22. (continued)

Compound	Number of Sites at Which Constituents was Detected	Concentration Range (ppm)	Median Concentration (ppm)	Promulgated Standards or Criteria (ppm)
Nitrate	31	0.01 - 51	0.22	10[c]
Nitrite	8	0.005 - 0.2	0.03	
Nitrogen (Kieldahl)	21	34-1,470	270	
Nitrogen (Organic)	9	4 - 100	50	
Nitrogen (Total)	1	505-505	505	
Phosphate	4	0.42-7	1.2	
Phosphorous	14	0.29-117	1.4	
Potassium	19	18-1,175	382	
Selenium	17	0.0008-0.05	0.02	0.01[a]
Silver	17	0.0008 - 0.035	0.012	0.05[a]
Sodium	37	12 - 2,574	693	
Sulfate	39	8-1,400	111	
Temperature (°C)	6	5-25	11	
Thallium	11	0.004 - 0.86	0.08	0.01[b]
Tin	3	0.16 - 2.0	0.23	
Total Dissolved Solids	28	390 - 31,800	4,890	20[c]
Total Organic Carbon (Nonpurgable)	33	20-14,500	1,000	
Total Solids	8	1,900-33,050	10,658	
Total Suspended Solids	32	23 - 17,800	276	
Vanadium	6	0.009 - 0.029	0.08	
Zinc	50	0.03 - 350	0.68	0.110[c]
pH (standard units)	59	5.4 - 12.5	6.69	6.5-9[c]

SOURCE: Reference 5, Reference 7, Reference 8, Reference 9, Reference 10, Reference 11, Reference 12, Reference 13, Reference 14, Reference 15, Reference 16, Reference 17, Reference 18, Reference 19

a Maximum contaminant level, EPA's drinking water standard.
b Concentration based on U.S. EPA verified reference dose from systemic toxicants and the assumption of a 70Kg adult consuming a liter of water per day.
c EPA's water quality criteria.

NOTE: The EPA is presently evaluating these data in a separate report titled Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics. This report is being prepared by NUS Corp. under contract 68-01-7310 as a background document for the work assignment "Criteria for Municipal Solid Waste Landfills."

TABLE 1. SUMMARY OF LEACHATE TREATMENT PROCESS CAPABILITIES

	BOD_5		COD		TKN		Fe		Zn		Ni		Comments
	Rem., %	Effl., mg/l	Rem., %	Effl., mg/l	Rem., %	Effl., mg/l	Rem., %	Effl., mg/l	Rem., %	Effl., mg/l	Rem., %	Effl., mg/l	
AEROBIC BIOLOGICAL PROCESSES													
Activated Sludge	95	100	95	500	70-95	10-100	96-99	10-40	96-99	3-10	60	0.25	θ_c = 6-10 days
Combined Leachate and Sewage	94-99	3-15	92-98	25-60	--	--	--	--	--	--	--	--	ratio <5%
Aerated Lagoon	99	5-60	92-98	300-800	40-70*	40-80	99	0.2	--	--	--	--	θ_c >10 days
Stabilization Pond	93-99	10-100	95	100-400	70-99	8-100	80-99	1-100	--	--	--	--	t >10 days
Aerobic Fixed Film*													
ANAEROBIC BIOLOGICAL PROCESSES													
Attached Growth	85-98	100-900	75-95	200-1000	--	--	80-99	5-25	80-99	0.5-10	10-80	0.1-1	θ_c >10 days
Suspended Growth	85-98	100-900	75-95	200-1000	--	--	80-99	5-25	80-99	0.5-10	10-80	0.1-1	θ_c >5 days
Leachate Recycle	NA	<100	NA	<5	NA	20-1000	NA	5-50	NA	0.2-1	NA	--	θ_c >500 days
PHYSICAL/CHEMICAL PROCESSES													
Coagulation	--	--	12	100-10,000	--	--	95-99	2-17	75-98	<1	--	--	Lime, alum, ferric chloride
Oxidation	--	--	10-50				99	<1	90	<1	--	--	Ozone, chloride permanganate
Reverse Osmosis	--	--	60-90** / 86-94	1000-8000 / <10	--	--	--	--	--	--	--	--	Raw Leachate / Pretreated Leachate
Ion Exchange	--	--	40-70	100-300	--	--	40-80	1-10	20-96	<1	14-96	<1	Commercial IX Resins and GG
Adsorption	--	--	75-99	<10	--	--	65-95	2-15	--	--	--	--	GAC and PAC

Rem. = Removal; Effl. = Effluent
*Insufficient data to make an adequate judgment; **TOC Basis

Attachment 14
(Source: Pohland and Harper, 1986)

Attachment 15
(Source: Pohland and Harper, 1986)

TABLE 13. SUMMARY OF LEACHATE TREATMENT PERFORMANCE AND DESIGN PARAMETERS FOR FULL-SCALE AERATED LAGOON FACILITIES

ITEM \ REFERENCE	(15)		(28)	(113-115)	(157)	(44a)			
Influent Quality									
BOD_5, mg/l	120	3000	10,000	800	5310	4500	3000	650	100
COD, mg/l	-	-	14,000	1500	7800	-	-	-	-
TOC, mg/l	-	-	-	455	2740	-	-	-	-
BOD_5/COD	-	-	0.71	0.53	0.68	>0.4	0.4	0.2	0.05
COD/TOC	-	-	-	3.3	2.8	-	-	-	-
TKN, mg/l	-	-	700	-	270	-	-	-	-
NH_3-N, mg/l	10	30	600	-	240	-	-	-	-
BOD_5:N:P	100:8:-	100:1:-	100:5:1	-	100:5:0.4	-	-	-	-
Fe, mg/l	60	120	700	-	60	-	-	-	-
pH	6.8	5.6	-	6.0	6.8	-	-	-	-
Temperature, °C	13-25	10-25	2-25	0-25	0-25	5-20	5-20	5-20	5-20
Q, m^3/day	355	45.4	303	37.9	216	-	-	-	-
Pretreatment				No		No	No	No	No
Flow equalization	No	No	No		τ=2d				
Lime addition	Yes	Yes	Yes		No				
Settling	τ=2d	τ=2d	Yes		No				
Neutralization	No	No	Yes		No				
Nutrient addition	No	No	Yes		Yes				
Preaeration	No	No	Yes		No				
Treatment									
BOD_5 loading, kg/m^3-day	0.01	-	0.33	0.01	0.76	0.03	0.03	0.005	0.001
COD loading, kg/m^3-day	-	-	0.47	0.02	1.1	-	-	-	-
τ, days	20	-	30	90	7	135	120	120	90
Post-treatment				No		No	No	No	No
Settling	τ=2d	τ=2d	No		τ=5.3 hrs				
Chlorination	Yes	No	No		No				
Chemical addition	No	No	H_2O_2		No				
Effluent Quality									
BOD_5, mg/l	10	920	-	-	50	25	25	25	25
COD, mg/l	-	-	-	-	415	-	-	-	-
BOD_5 removal, %	92	70	-	-	99	>99	>99	96	75
COD removal, %	70	-	-	-	95	-	-	-	-
TKN, mg/l	-	-	-	-	100	-	-	-	-
NH_3-N, mg/l	-	-	-	-	80	-	-	-	-
NH_3-N removal, %	-	-	-	-	66	-	-	-	-
Fe, mg/l	1	10	-	-	0.2	-	-	-	-
Fe removal, %	98	92	-	-	>99	-	-	-	-
pH	7.5	7.4	-	-	8.1	-	-	-	-
Effluent Disposal	Surface water for both		POTW	Ridge and furrow land disposal, rate: 4.7 l/m^2-day	Stabilization pond	Spray irrigation for all four cases			

TABLE 18. SUMMARY OF LEACHATE TREATMENT PERFORMANCE AND DESIGN PARAMETERS FOR FULL-SCALE STABILIZATION POND FACILITIES

ITEM \ REFERENCE	(157)		(166)	(187)	(230)
Influent Quality					
BOD_5, mg/l	28	21	21,100	1340	-
COD, mg/l	370	330	35,700	2460	2500
TOC, mg/l	92	74	-	-	-
BOD_5/COD	0.08	0.06	0.59	0.54	-
COD/TOC	4.0	4.5	-	-	-
TKN, mg/l	92	76	-	-	90
NH_3-N, mg/l	81	63	440	168	50
BOD_5:N:P	100:290:5	100:300:10	100:2:-	100:8:-	-
Fe, mg/l	-	-	1400	-	750
pH	8.4	8.5	5.2	-	6.0
Temperature, °C	18-23	18-23	0-25	0-18	0-25
Q, m^3/day	77.8	77.8	4	150	949
Pretreatment			No	No	
Chemical Addition	No	No			Yes
Biological Treatment	Yes	Yes			No
Settling	Yes	Yes			Yes
Nutrient Addition	No	No			No
Treatment					
BOD_5 loading, kg/m^3-day	<0.01	<0.01	0.70;0.35; 0.23	0.01	-
COD loading, kg/m^3-day	<0.01	<0.01	1.2;0.60; 0.40	0.03	-
τ, days	63	44	30;60;90	90	-
Post-treatment	No	No	No	No	No
Effluent Quality					
BOD_5, mg/l	21	13	4650;220; 10	100	-
COD, mg/l	330	160	9500;400; 120	-	-
BOD_5 removal, %	25	38	77;99;>99	93	-
COD removal, %	11	52	73;99;>99	-	-
TKN, mg/l	76	20	-	-	-
NH_3-N, mg/l	63	12	130;70;3.5	-	-
NH_3-N removal, %	22	81	70;84;99	-	-
Fe, mg/l	-	-	320;120;1.0	-	-
Fe removal, %	-	-	77;91;>99	-	-
pH	8.5	...3	6.5;6.8;7.3	-	-
Effluent Disposal	Stab. Pond	Surface Water	Surface Water	Surface Water	Surface Water

- Data not given

TABLE 33. FULL-SCALE LEACHATE TREATMENT FACILITIES USING A PHYSICAL/CHEMICAL PROCESS

Reference	Process	Process Description	Location
26	Precipitation	Lime addition for heavy metal removal.	North Hempstead, New York
133	Coagulation and Adsorption	Alum and polymer addition for pretreatment prior to AC adsorption for organic and heavy metal removal.	Franklin County, Pennsylvania
178, 179	Adsorption	NaOH addition for pretreatment prior to AC adsorption for removal of toxic organics, most classified as priority pollutants.	Love Canal, New York
231	Chemical Addition	Chemical addition prior to treatment by aerated lagoon and activated sludge.	Pennsylvania (2 landfills)
245-248	Precipitation; NH_3 Stripping; Nuetralization	Lime addition for heavy metal removal and to raise pH; Air stripping of NH_3 at alkaline pH using a lagoon; Sulfuric and phosphoric acid addition for neutralization.	Bucks County, Pennsylvania

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SUBTITLE D ISSUE PAPER ON LEACHATE RECIRCULATION

Issue: How should the Subtitle D criteria revisions address leachate recirculation?

Discussion:

The major focus in revising the Subtitle D criteria is to base the criteria revisions on a "dry landfill" concept. This concept requires that minimal liquids be allowed into the landfill in order to minimize the generation of leachate and to prevent potential contaminant migration to the ground water. In reviewing this concept, the need to address how leachate generated at the landfill should be handled and treated arises.

One method in treating leachate is through leachate recirculation through the landfill itself. This treatment method has been researched and utilized at some landfills since the early 1970's. It provides certain benefits in increasing stabilization of the landfill over a shorter period of time; improves leachate quality; and improves the quality and increases the quantity of methane gas production at the landfill. However, there are certain drawbacks to using leachate recirculation as a treatment method. One of these drawbacks is that by reintroducing leachate into the landfill, the amount of liquids in the landfill could increase considerably thus contradicting the "dry landfill" concept. There are other potential environmental impacts associated with leachate recirculation which are dicussed further in this paper.

In reviewing the benefits and drawbacks of using leachate recirculation as a treatment method, the issue on how to address leachate recirculation in the Subtitle D criteria revisions has become a major issue.

Options:

In reviewing the issue there are several options that have been developed on how to address leachate recirculation. These options are as follows:

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1) Allow leachate recirculation as a full scale method of leachate treatment at all landfills, regardless of landfill design (with or without leachate collection system)

2) Allow leachate recirculation as a leachate treatment method only at landfills with leachate collection systems.

3) Allow leachate recirculation as a leachate treatment method at landfills with leachate collection systems only during the active life of the landfill.

4) Ban leachate recirculation as a leachate treatment method at all new landfills and phase out over a period of time at landfills currently using this method.

5) Allow leachate recirculation at new and existing landfills with leachate collection systems for a certain period of time until an alternative method for treatment can be developed.

Pros and Cons:

There are several pros and cons associated with the options listed in the previous section and are discussed below.

Option 1 would contradict the "dry landfill" concept and increase the potential of contaminant migration to the ground water particularly at units that do not have efficient leachate collection systems. This option is not feasible at landfills that do not have a leachate collection system. Additional pros and cons are listed in Table 1.

Option 2 also contradicts the "dry landfill" concept but only allows this method to be performed at landfills that have a leachate collection system. This option however would cause problems once the landfill is capped, since the revised criteria are requiring the final cap to control any liquids from entering the landfill following closure. If leachate were to be recycled after closure; then the cap would have to be designed to handle the leachate, thus contradicting the cap

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performance standard (no infiltration into the waste after closure) in the revised criteria. Other pros and cons related to this option are listed in Table 1.

Option 3 is a variation of Option 2 by only allowing leachate recirculation during the active life of the landfill at sites with leachate collection systems. This would delete the necessity to design the cap to handle leachate recirculation after closure, however itprovides another problem in what to do with the leachate collected after final closure of the landfill. Again this option contradicts the "dry landfill" concept.

Option 4 supports the "dry landfill" concept, however it may cause financial burdens and logistical problems at landfills located in remote areas not having access to alternative leachate treatment methods, e.g., sanitary sewers. Treatment facilities would be required to build a treatment facility on site at new and existing landfills that do not have alternative methods for handling leachate thus increasing the financial burden to the operator/owner. In turn this treatment facility may only handle small amounts of leachate in the first couple of years and must be designed to handle leachate that will change composition over time. In addition, following closure of the site when no leachate is being generated, the owner/operator is left with a treatment facility that has no further purpose. Other pros and cons on this option are listed in Table 1.

Option 5 is a variation of Option 4 that supports the "dry landfill" concept but allows a time period when both new and existing landfills may use the method of leachate recirculation as a short-term method. This will allow time for the operator/owner to investigate alternative methods and will give the time for leachate to generate to an amount and composition that will help the operator/owner in determining alternative treatment methods. It also allows time for the operator/owner to collect finances to support the construction of a treatment facility on-site if necessary. However, there is still the problem of potentially being left with a treatment facility, if required, with no further purpose following landfill closure.

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TABLE 1: OPTIONS ON THE LEACHATE RECIRCULATION ISSUE

Options	Pros	Cons
1 Allow leachate recirculation at all landfills regardless of design	• Accelerates stabilization of landfill • Promotes gas formation (pro if gas is recovered at site) • Improves leachate quality • Economically feasible for remote sites with no alternative for leachate treatment	• Contradicts 'dry landfill' concept • Promotes gas formation (con if gas is not recovered at site) • Daily cover (especially clayey soils) impedes leachate recirculation • Greater potential of contaminant migration • Not feasible at landfills without LCS
2 Allow leachate recirculation at landfills with LCS	• Accelerates stabilization of landfill • Promotes gas formation (pro if gas is recovered at site) • Improves leachate quality • Economically feasible for remote sites with no alternative for leachate treatment	• Contradicts 'dry landfill' concept • Promotes gas formation (con if gas is not recovered at site) • Daily cover (especially clayey soils) impedes leachate recirculation • Greater potential of contaminant migration • May result in build up of hydraulic static head • Increases potential of clogging LCS • Increases air pollutant releases • Increases odor problems • Increases potential of leachate pollutant releases due to drift and/or runoff • Contradicts revised criteria's final cover performance standards
3 Allow leachate recirculation at landfills with LCS only during active life	• Accelerates stabilization of landfill • Promotes gas formation (pro if gas is recovered at site) • Economically feasible for remote sites with no alternative for leachate treatment • Maintains revised criteria final cover performance standards	• Contradicts 'dry landfill' concept • Promotes gas formation (con if gas is not recovered at site) • Daily cover (especially clayey soils) impedes leachate recirculation • Greater potential of contaminant migration • May result in build up of hydraulic static head • Increase potential of clogging LCS • Increases air pollutant releases • Increases odor problems • Increases potential of leachate pollutant releases due to drift and/or runoff
4 Ban leachate recirculation at new landfills and phase out at existing landfills praticing leachate recirculation	• Maintains 'dry landfill' concept • Allows time for existing landfills to investigate alternative methods • Decreases potential migration problems	• Possible financial burden to remote sites • At new landfills, would have to design treatment facility to handle leachate that changes composition over time • Treatment facilities at new landfills would not be used at full potential the first couple of years • After closure left with treatment facility with no further purpose
5 Allow short term recirculation at new and existing landfills with LCS	• Maintains 'dry landfill' concept • Allows time for new and existing landfills to investigate alternative methods • Allows time to determine the type of leachate that must be treated • Provides time for owo to collect finances for alternative treatment	• Possible financial burden to remote sites • After closure left with treatment facility with no further purpose

Attachment 18 (Cont.)